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THE IMPACT OF *MASHRABIYA* ON BUILDING ENERGY PERFORMANCE AND SOCIAL CULTURAL ASPECTS IN HOT CLIMATES

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De Montfort University, Leicester, United Kingdom

بسم الله الرحمن الرحيم

In The Name of Allah, The Most Beneficent, The Most Merciful

Declaration

To the best of my knowledge, I confirm that the work in this thesis is my original work undertaken for the degree of Doctor of Philosophy in the Faculty of Faculty of Art, Design and Humanities, Institute of Architecture, De Montfort University. I confirm that no material of this thesis has been submitted for any other degree or qualification at any other university.

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To my parents' souls

Shafiaa

Abstract

With the adoption and influence of Western designs, the architecture in Jeddah has experienced a loss in Hejazi architectural identity resident's lack of privacy, contributing to the increase in energy consumption. In this study, a clear outline of the background to the causes and the effects of the increase in energy consumption will be elaborated focusing on the actual specific research area of Jeddah.

In the construction of buildings, the shift from traditional to contemporary architecture resulted in the use of air condition (AC) to improve the indoor environmental quality due to the hot climatic conditions. The over-use of air condition in residential buildings led to the increase in energy usage which resulted in the government suspending the subsidy for electricity for residents followed by the increase in electricity tariffs in an attempt to minimise the usage of electricity.

The research study aims to address the problems associated with the shift in architectural and the effect of operational systems by analysing the impact of *mashrabiya* on energy performance and identifying the social cultural needs of residents to preserve privacy and Hejazi architectural identity in residential buildings in Jeddah, Saudi Arabia.

The research approach included an initial pilot survey to ensure the effectiveness of the research methods, questions, and overall research procedure. In this survey the researcher interviewed 3 residents who owned and built the villas for 3 days. The survey questions addressed mainly the three areas of the research which include energy consumption, identity, and privacy as well as mashrabiya. According to the pilot survey results all the residents interviewed acknowledged the fact that re-instating mashrabiya would provide privacy and enhance Hejazi architectural identity. In the area of energy consumption, the results indicated various factors that impact on energy consumption including the area, number, and behaviour of people.

The relevant information identified from the literature review in relation to the objectives of this research, the historic facts about *mashrabiya* in terms of energy performance, particularly in Saudi Arabia, were combined with data collected through 261 online questionnaires. The respondents also included 8 specialists' interviews from 4 government organisations and 48 residents from Albasateen district as well as observations and results from measurements which were then used to calculate the entry information to simulate the modelled case study villa. A range of simulations were than conducted to evaluate the building performance in terms of lighting and energy consumptions together with indoor environmental quality' and social cultural related issues.

According to the specialists' interview results, 100% state that *mashrabiya* is the most significant Hejazi architectural element which provides identity. In relation to the residents' privacy the online and interview results show 94% of respondents who claim to have privacy while from the observations and further investigation on privacy 100% use window treatment such as curtains, blackouts, and shutters to provide privacy which indicates that they lack privacy. Therefore, the use of *mashrabiya* will provide both identity and privacy. One of the research areas included the energy usage, the results from simulation showed significant reduction in total energy usage in an existing villa case study compared with the villa case study with gypsum *mashrabiya* with large hole design. The results showed a decrease from 106, 114 kWh to 94, 115 kWh a total reduction of 11, 999 kWh (11%).

It can therefore be concluded that if *mashrabiya* is re-instated it has great potential to restore not only the Hejazi architectural identity but will also provide residents' privacy while reducing the energy consumption as a shading device in residential buildings in the city of Jeddah.

Keywords: Mashrabiya, Hejazi architecture, Energy Performance, Simulation, Architectural Identity, Privacy, Hot Climate.

Acknowledgments

This thesis would have not been possible without the support, dedication and enthusiasm and patience of my supervisors Professor Ahmad Taki and Professor Birgit Painter.

I would also like to thank all my family for their prayers and support particularly my brothers Fawaz Bin Rafaah for being my immediate support in the UK and Rashed Bin Rafaah for technical support.

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Abbreviations

Abbreviations	Explanation
ARAMCO	Officially the Saudi Arabian Oil Company, most popularly known just as Aramco (formerly Arabian-American Oil Company), is a Saudi Arabian national petroleum and natural gas company based in Dhahran.
AutoCAD	Is a computer-aided, industry standard tool that allows many different types of designers to create diverse kinds of drawings and designs.
GCCC	Gulf Cooperation Council Countries, political and economic alliance of six Middle Eastern countries: Saudi Arabia, the United Arab Emirates, Kuwait, Bahrain, Oman, and Qatar.
GCC-STAT	Gulf Cooperation Council Statistical Centre
HVAC	Heating, Ventilation and Air conditioning
AC	Air Condition
JM	Jeddah Municipality
KSA	Kingdom of Saudi Arabia
SCTNH	Saudi Commission for Tourism and National Heritage
SEC	Saudi Electricity Company
SEEC	Saudi Energy Efficiency Centre
PMV	Predicted Mean Vote
RH	Relative Humidity
PPD	Predicted Percentage of Dissatisfied
clo	Clothing Coefficient
SHGC	Solar Heat Gain coefficient

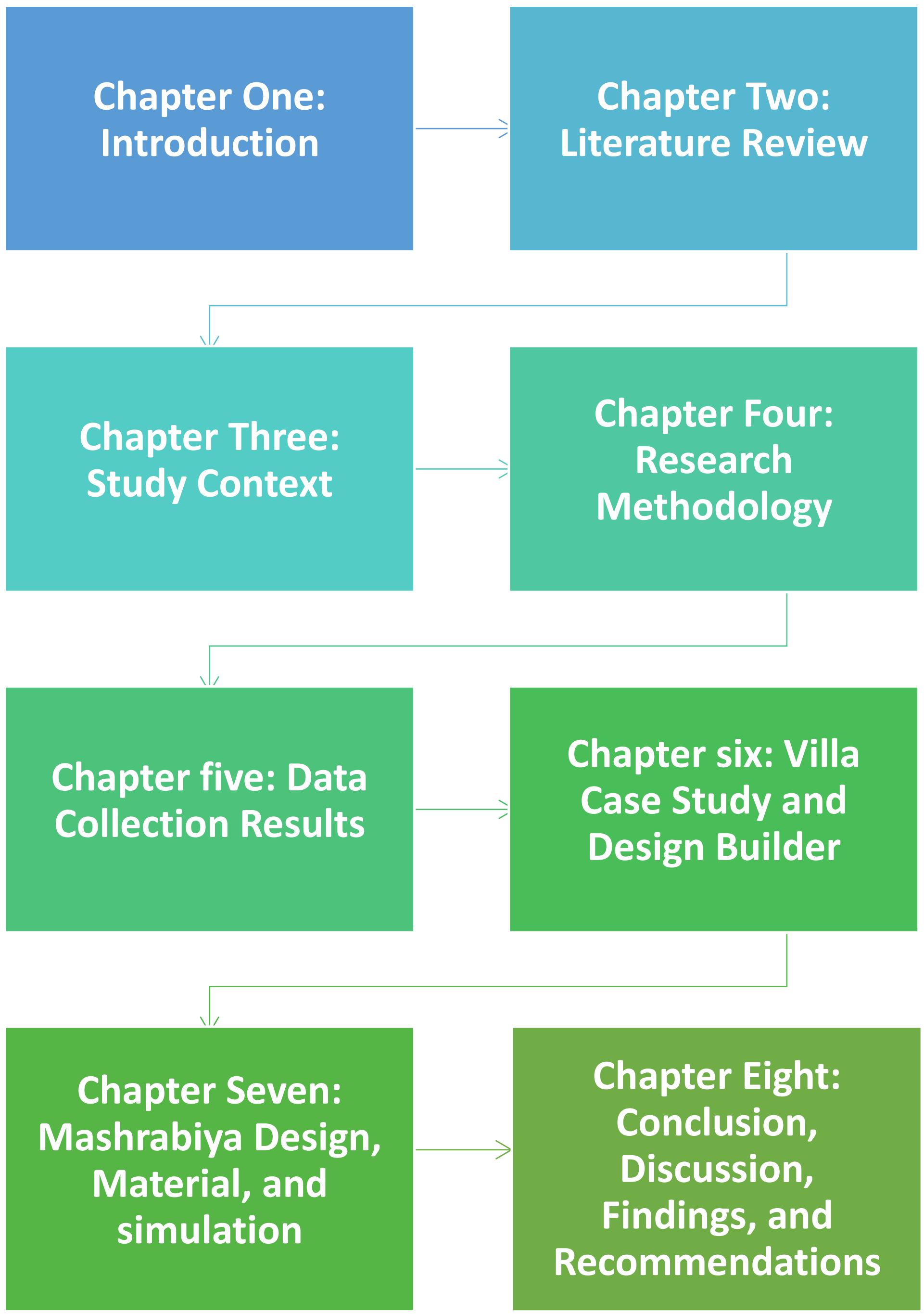
Glossary of Terms

Term	Meaning
Hajj	The fifth pillar of Islam is a pilgrimage to Mecca during the month of Dhu al-Hijja; at least once in their lifetime a Muslim is expected to make a religious journey to Mecca and the Kaaba.
Energy consumption	Energy consumption is the amount of energy or power used. Often refers to the electrical energy over time supplied to operate an electrical appliance.
Hijaz	The Hijaz region constitutes Taif, Makkah, Jeddah, and Medina. The Hijaz consists of the cities and those who belong to them (Yamani, 2004; 2009).
Islam	The religion of the Muslims, a monotheistic faith regarded as revealed through Muhammad as the Prophet of Allah.
Mashrabiya (Roshan)	Architectural device made of a combination of wood strips and screens, which is commonly used for large external openings.
Quran	The Islamic holy book
Simulation	The representation of the behaviour or characteristics of one system through the use of another system, especially a computer program designed for the purpose.
Indoor environment al quality'	Is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55)?
Umrah	Umrah is a pilgrimage to Makkah-Saudi Arabia performed by Muslims that can be undertaken at any time of the year.
Old Jeddah '' AL balad''	Al balad is the historical area of Jeddah, Balad can literally be translated as "The Town." Balad is the historical centre of the city of Jeddah.
Privacy	The privacy of family members especially visual privacy to the woman is important from an Islamic point of view. (Al kodmany 1999) defines visual privacy as the ability to carry out everyday activities hidden from the eyes of outsiders or without fear of being observed by them.

Heritage Building	"Heritage building" means a building possessing architectural, aesthetic, historic or cultural values which is declared as heritage building by the Planning Authority/Heritage conservation committee or any other competent authority in whose jurisdiction such a building is situations.
Architectural Identity	The local architectural identity of any society is an important life container which reflects, among other things, its cultural values and meanings that evolve over time. Nooraddin, H (2012)
Hot Climate	Hot desert has a mean annual temperature of at least 18°C and no more than 200 mm of precipitation annually.
Relative Humidity	The ratio of the partial pressure (or density) of the water vapor in the air to the saturation pressure (or density) of water vapor at the same temperature and the same total pressure
Predicted Mean Vote	A dimensional metric defined based on the empirical fit to the human sensation of indoor environmental quality'.
Airspeed	The rate of air movement at a given point in time regardless of the direction.
Predicted Percentage of	Relative metric defined to predict the percentage of any population that will be dissatisfied with the environment.
Clothing Coefficient	A unit used to express the thermal insulation provided by garments and clothing ensembles.
Indoor environmental quality'	Indoor environmental quality' is that condition of mind that expresses satisfaction with the thermal environment.

Document Structure

The Impact of *Mashrabiya* on Building Energy Performance and Social Cultural Aspects in Hot Climates



CHAPTER ONE

1. Introduction

This chapter includes nine important research aspects that researchers consider when carrying out a research. The main area that needs to be thought about cautiously include the research background which provides the context of the topic. In addition, the statement of the problem, providing knowledge which enables the researcher to find appropriate research methods to collect data for analysis and solution to the problem. In order to execute the research topic, the research follows research questions, objectives, and the significance of the research in the society hence this chapter shows the summary of these key areas and the relationship to the research. There is also detailed outcomes and a list of the beneficiaries as well as the limitations of the research.

1.1 Research Background

A vital part of the identity, culture and pride of a country is embedded within its unique architectural heritage. The major principles in Hejazi architecture (which are influenced by Islamic Architecture) primarily focuses on individual hierarchical needs, including the specific religious, environmental, social, and physical requirements specified in Islam. The Hejazi architecture which is intertwined with religion includes privacy, natural ventilation, and light. According to (Adas, 2013) Hejazi architecture is characterised by walls built from mangbi stones and plaster with *mashrabiya* on the facades. While the wider regions of Saudi Arabia have experienced major transitions in traditional architecture. In recent years, traditional Hejaz architecture in Jeddah has changed drastically because of the widespread adoption of Western-style architecture. In response to local climatic conditions, residential buildings in Saudi Arabia typically have extremely high levels of energy consumption for lighting and cooling, often reaching approximately 50% of all household usage (Alaidroos and Krarti, 2015). This shift to western style shows the negative impact of energy usage as highlighted in residential buildings above. (Al-Saadi and Budaiwi, 2007) state that as residential building experience increase in energy consumption 70% of this is as a result of poor envelope design such as walls, roofs and windows. Not only do these windows increase heat transfer levels, but they also prevent the levels of privacy that are required by the Islamic religion. This leads many residents to install internal and external shutters and heavy curtains; however, coverings typically detract from the aesthetic appeal of houses and fail to represent the Hejazi architectural identity that was once distinct in Jeddah.

1.2 Statement of the Research Problem

The over-population in Saudi Arabia with a recorded growth of 1.54 % yearly as stated by (Alaidroos and Krarti, 2014) led to the demand in housing resulting in the shift from traditional to contemporary style with buildings reflecting foreign culture. This action resulted in the introduction of the excessive use of Air Condition as residents aimed to improve the indoor environmental quality' however, contributing to the increase in energy consumption. In order to control energy usage, the government increased the electricity tariffs and stopped subsidising electricity costs. (SEC, 2017)

While this issue of the constant growth in the consumption of energy affects the Saudi populace, it is also the government's responsibility to ensure it is controlled through construction of homes that are energy efficient and monitoring appliances that increase energy consumption significantly. It should be noted that this problem has been researched by several researchers including (Saleh, 1990; Alsanea, 2002; Aldawoud, 2013) though all focussing on different architectural elements including walls, roofs, thermal insulation, and windows, and attaining a certain percentage decrease in energy consumption in various parts of the country. However, there is no research to date that has incorporated all the results and then combined them to further extend from their individual conclusions addressing the social cultural aspects. The Saudi Electricity Company (SEC) has recently raised the price of electricity by 70%. This announcement was formalised in 2018. This information is being tracked as it contributes effectively to the research.

Many researchers have focussed on examining the reduction in energy consumption through the use of various building materials, as well as through the use of structure and insulation see table (2-9). Their results illustrate the vital role played by these considerations in lowering energy consumption. This is evidenced by a research carried out by (Aldossary et al., 2014) on the energy consumption pattern in domestic homes in a hot and humid climate. The results on multiple case studies showed that high energy consumed is as a result of lack of thermal insulation for both walls and roofs. This led the Saudi government to decree that all buildings must use thermal insulation (Saudi Electricity Company SEC, 2010) in 2014 made change in the Saudi building code then in 2017 was developments. This research aims to go a step further and examine the use of *mashrabiya*, looking at the impact that this might have on reducing energy consumption in residential buildings.

Researchers have identified the climate as the major cause of energy consumption, with energy consumption in buildings increasing due to the negative impact of extreme climate effects. Natural ventilation has been suggested as a viable solution to the issue of cooling the internal environment of buildings or reducing energy demand, even in hot climates (ibid). Historically, natural lighting and ventilation including the control of solar gain has been achieved using *mashrabiya*. As stated by (Aksamija, 2015) Mashrabiya which includes both cultural and social functions is also a climate regulator exchanging hot air for cold air leaving the indoor temperature comfortable for the users resulting in less use of air conditioner which consumes more energy. As mentioned by (Alshareef, 1986) reduction of solar gain is achieved as *mashrabiya* balusters prevent the glare which can potentially increase indoor temperature. Finally, (Ajaj, 2014) confirms how using *mashrabiya* provides natural air and lighting enhancing indoor environmental quality. While there is much information on other aspects of *mashrabiya* such as its aesthetic characteristics and lighting however, none of the researchers focussed on the use of *mashrabiya* in relation to energy consumption. This research therefore aims to investigate the use of *mashrabiya* and all its functions to reduce energy consumption in a hot climate. The fact that people use shutters to increase the level of privacy shows that the usage of *mashrabiya* may resolve this problem and, further, enhance the identity of the Hejazi architecture in Jeddah. The further steps taken by the government in order to reduce the increase of energy consumption can be found in section 2.2.3.

In reference to the research problem, the aim of the study is to investigate the effectiveness of *mashrabiya* in residential buildings energy performance in a hot climate fig (1-1). This topic was born out a strong interest and the desire to solve this enduring continuous increase in energy consumption in Saudi Arabia.

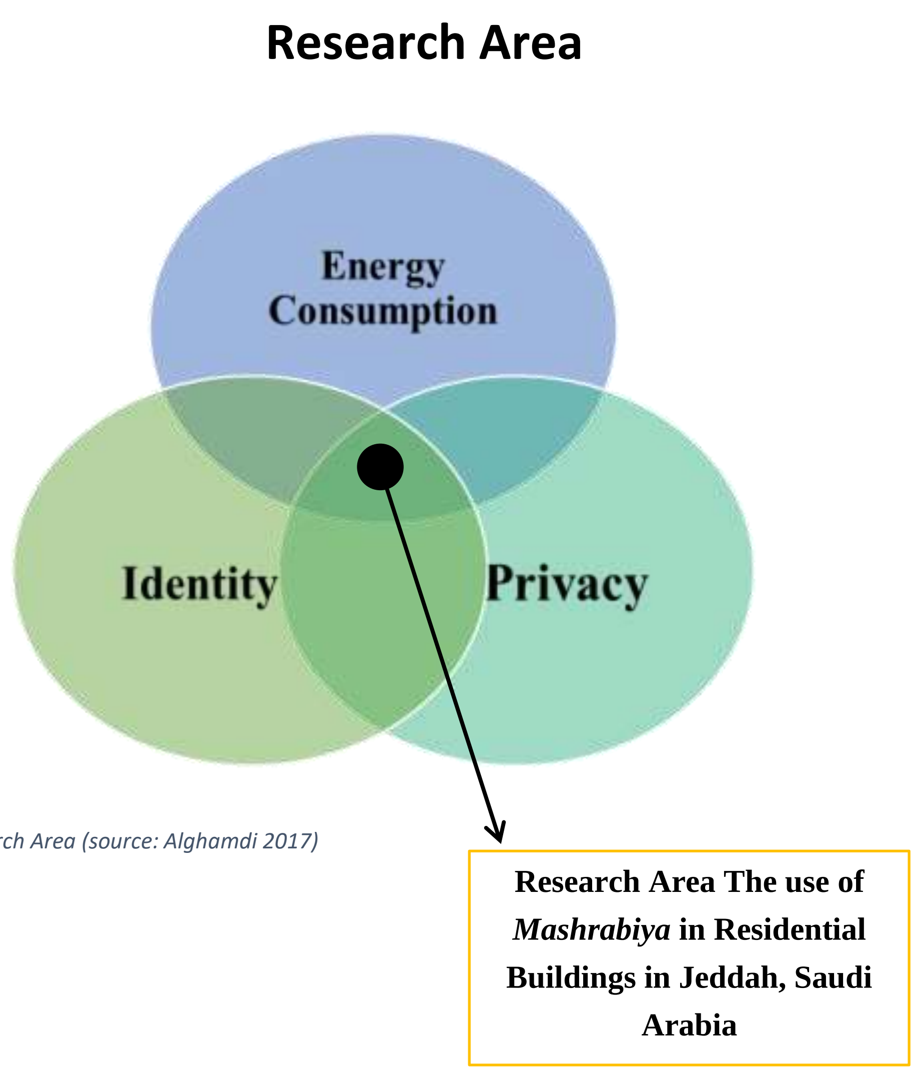


Figure 1-1Research Area (source: Alghamdi 2017)

1.3 Research Questions

1. Which are the architectural factors and operational systems that affect energy consumption in residential buildings in hot climate.

2. How would the use of *mashrabiya* reduce energy consumption in residential buildings whilst providing privacy and retaining building characteristics and sense of Hejazi architecture identity in Jeddah.

1.4 Research Aim and Objectives

This study aims to examine the impact of *mashrabiya* on energy performance and an important aspect of social cultural life in contemporary residential buildings in Jeddah. This aim will be addressed through following the objectives.

1. Identify common architectural factors and operational systems that affect the energy consumption of residential buildings in the context of Jeddah, Saudi Arabia.

2. Examine the privacy and social cultural needs of residents in privately owned buildings in Jeddah.

3. Investigate the effects of *mashrabiya* on the level of privacy and identity in residential buildings in Jeddah.

4. Assess the energy performance of the existing case study villa using the Dynamic Thermal Simulation Tool.

5. Evaluate the impact of *mashrabiya* façade alternatives on indoor environmental quality' and energy consumption as applied to the villa case study in item 4.

1.5 Research Methodology

As will be outlined in detail in chapter 4, this study will follow a mixed methods approach. Initially, a critical literature review will be conducted in sustainability and architectural design with the aim of identifying common architectural and operational systems that affect the energy consumption of residential buildings in hot climates. The review of the literature will also critically evaluate both the traditional and modern application of *mashrabiya*.

During the data collection phase of this investigation, online questionnaires were posted and 261 responded. In addition, 48 interviews were conducted with residents from Albasateen District who owned and built houses in Jeddah, a major city in Saudi Arabia. The interviews sought to assess privacy and social needs. These findings will be supplemented by interviews conducted with officials from four government organization specialists including Saudi Energy Efficiency Centre (SEEC), Saudi Electricity Company (SEC), Jeddah Municipality (JM) and the Saudi Commission for Tourism and National Heritage (SCNH), in anticipation to obtain rich insights into the social and cultural identity aspects as well as energy consumption in existing privately owned buildings.

The following stage of the study will involve case studies of typical villa in Albasateen district in Jeddah to examine and assess building energy performance using the Dynamic Thermal Simulation tool. The characterization of the villa in the case study will be used to derive the required input information for the Design Builder software. A range of simulations will then be conducted to investigate how *mashrabiya* can potentially reduce energy consumption for this case study villa, focusing on lighting, thermal analysis, and indoor environmental quality' . Based upon the findings, a set of interventions will then be proposed to find out the reduction in energy consumption for the case study villa through different designs of *mashrabiya*.

In summary, the impact of low energy retrofit *mashrabiya* on privacy and social cultural issues, together with the perception of human indoor environmental quality, will be examined using interviews and online questionnaires. This primary data, together with the secondary data from literature review and the predicted outputs from the dynamic thermal simulations, will be used to devise a theoretical design for the prototype *mashrabiya* fig (1-2). Chapter 4 of this research will include further detailed discussion on the research methods used.

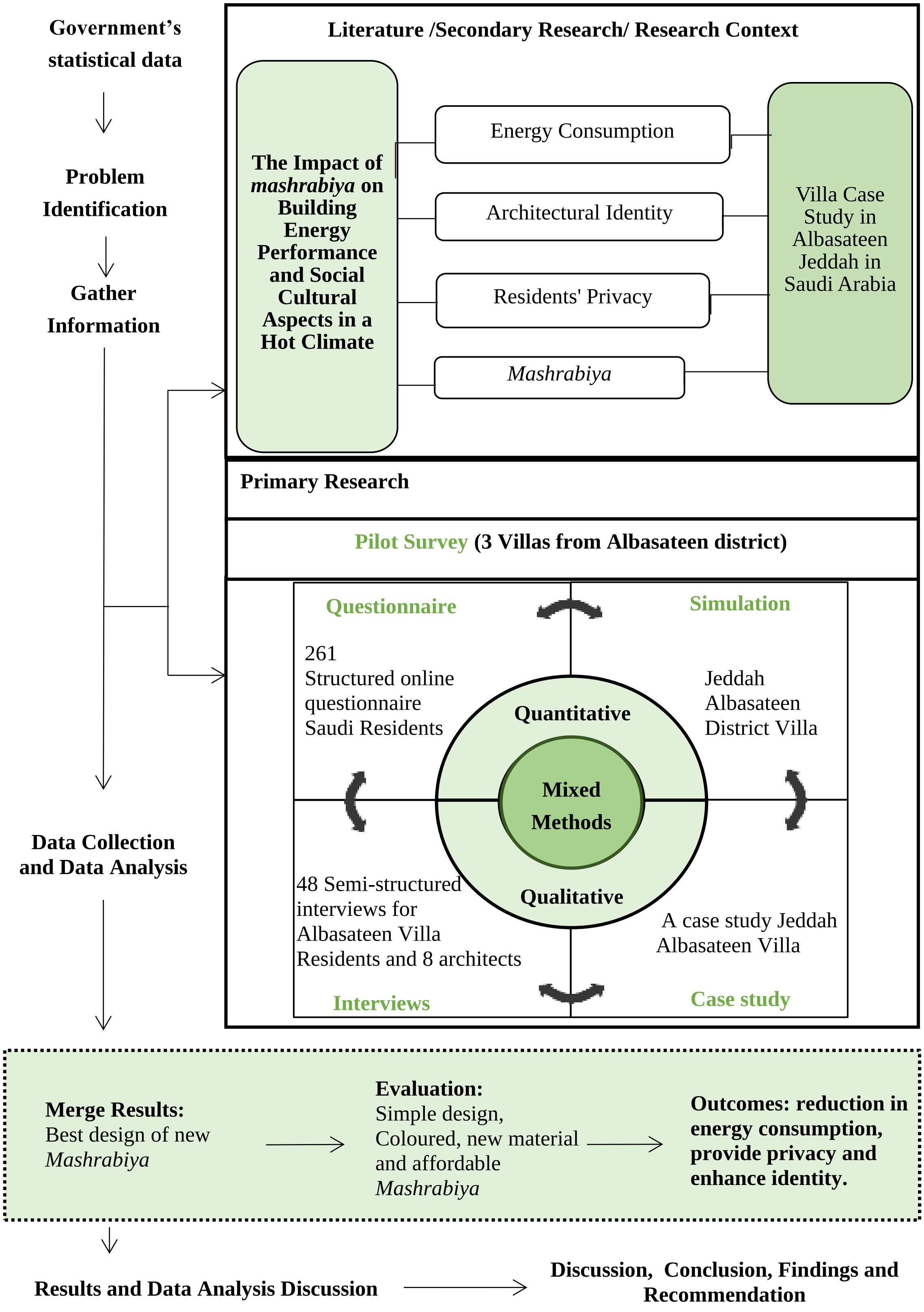


Figure 1-2 Research Procedure

1.6 Research Outcomes and Contribution

This research seeks to create a modern *mashrabiya* design to function as an indoor climate modifier in the Hejaz region of Saudi Arabia, specifically focusing on its application for providing privacy, cultural identity, and the reduction of energy consumption in residential buildings. The findings will enable municipal councils and decision makers in Jeddah to convince residents in terms of using *mashrabiya* in new buildings.

This research may also prove beneficial to other researchers interested in energy performance in buildings, especially those focused on hot climates. The recommendations provided here will enable other researchers to extend from the present concepts and ideas.

1.7 Support for this Research

This study has been undertaken with the cooperation and support of:

- Jeddah Municipality
- Jeddah University
- Ministry of Housing
- Saudi Electricity Company
- Saudi Energy Efficiency Centre
- The Saudi Commission for Tourism and National Heritage

1.8 Research Structure Summary

The main objective of this study is to determine whether *mashrabiya* can reduce energy consumption in residential buildings whilst observing social cultural aspects. The research will highlight if the question has been addressed and provide recommendations for potential further study.

This thesis is organised into eight chapters, with individual sections that address the various important aspects of the discussion. The introductory chapter outlines the aims and objectives of the current research, stating the required actions to acquire data to enable comprehensive analysis of the subject matter, namely an examination of the effectiveness of *mashrabiya* in reducing energy consumption.

Chapter two consists of a comprehensive review of the literature on energy consumption, privacy, identity, *Mashrabiya* and factors that otherwise have an impact on architecture in Saudi Arabia. It highlights the unanimous agreement by several authors regarding the increase in energy consumption, noting differences in the causes that have been used to explain this phenomenon. The definition of *mashrabiya* reveals its historical effectiveness as hidden in its functions. *Mashrabiya* was used in the past not only for identity purposes but also to ensure greater privacy and air regulation for indoor environmental quality.

The third chapter concentrates on Jeddah as a case study and factors that impact on energy performance in residential buildings. The main aim of the case study is to show the contributory factors that led to the increase in energy consumption such as the increase in population which led to the shift from traditional to contemporary architecture.

In the fourth chapter, an explanation of the research methods and epistemological considerations is given, namely positivists, constructivists, and pragmatists, and how these are linked to the project. This also shows the use of mixed methods research, including qualitative and quantitate approaches and how they are connected to the perspectives adopted in this research. The sampling of the subjects is also discussed, followed by a brief outline of the strengths and weaknesses of the chosen research methods and the solutions developed to address any predicted problems.

The fifth chapter, describes the findings from the main data collection activities, including online questionnaires from general residents, interviews with specialists and Albasateen residents. The chapter also includes data from observations, measurements and photos taken during the interview. Included in this is the discussion and the interpretation of results from all the data in this chapter related to Hejazi architecture identity and resident's privacy in residential buildings.

Chapter six describes the case study of an existing villa and the associated simulation. The parameters of the villa are simulated to determine the outcomes of the operative temperature, daylight, solar gain, and total energy consumption to evaluate the case study villa performance in terms of internal indoor environmental quality' conditions and energy consumption.

In chapter seven, the simulation process included the addition of different types of *mashrabiya* to an existing case study villa. Similar parameters as in chapter six were simulated to investigate the impact of *mashrabiya* on indoor environmental quality and energy consumption. These results were then compared to the ones in the existing villa confirming that gypsum *mashrabiya* design two with large holes is more effective in reducing energy consumption.

Chapter eight draws discussion, conclusions, findings, and recommendations regarding the research.

CHAPTER TWO

2. Literature Review

2.1 Introduction

The literature review presented herein has been sub-divided into two parts, which focus on energy consumption and social cultural aspects, including issues of architectural identity and resident's privacy, with the aim of addressing the objectives while elaborating on the issues surrounding the main research question. While the question seeks to determine the impact of *mashrabiya* on energy performance in residential buildings in a hot climate, the researcher aims to review literature to highlight factors that contribute to the increase in energy consumption. The explanation and references would show the status of energy consumption from past to present. This will include identifying factors contributing to the increase in energy consumption in residential buildings, At the same time the history of *mashrabiya* will be discussed through secondary research, showing the effectiveness of *mashrabiya* from the period it was introduced to its abandonment.

2.2 Energy Consumption

2.2.1 Energy Consumption Levels Worldwide

Energy is a vital commodity around the world, as the need for development requires the use of energy. Connections between countries are made possible due to technological communication and transportation. The development of countries can positively affect national economies, with corresponding increases in quality of life and increased population, leading to greater demand for accommodation and an escalation in energy consumption. The summary below reveals the connection between increases in energy consumption and the factors that affect global energy usage, as well as the role specifically played by the Middle East, particularly Saudi in which the case study will focus on.

Local, regional, and national factors such as modernisation, global warming and population growth contribute to the rise in energy consumption, particularly the architectural side, with the building sector responsible for over a third of global energy consumption (IEA, 2013). Developed and developing countries both contribute to the increase in energy consumption, although, to be specific, industrialised countries contribute more to this increase than poor countries, with the shift from wood burning to the industrial-level generation of electricity.

In a global context, the Gulf countries have been rated globally as amongst the highest in the world in terms of energy consumption, hence, there has been a focus in the region on the reduction of energy usage, with countries with the highest percentage usage being identified and listed in the world statistics.

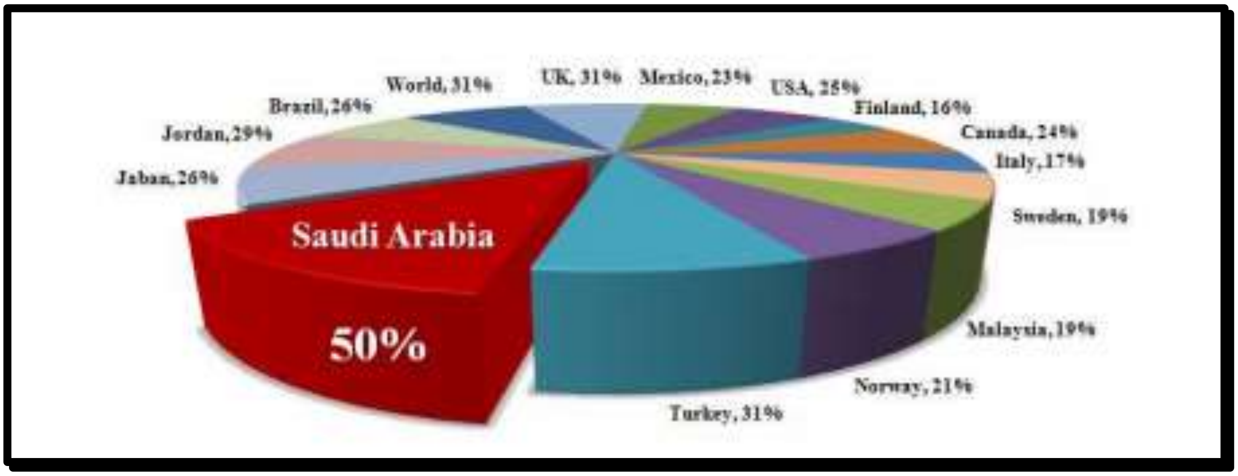


figure 2- 1 Saudi Arabia Electrical Energy Consumption compared to international consumption in the same sector (Source: Al-Ghamdi, Alshaibani (2017)

2.2.2 Energy Consumption in The Middle East, GCC

The history of energy production and trade has affected the world stability and security, with energy usage becoming increasingly essential to the proper functioning of societies. The period between 1970 and 1980 was characterised by a worldwide energy crisis. The Middle East has been both a producer and a supplier of energy figure (2-2). According to this diagram, while the Middle East is the main producer of oil, it is also the largest energy consumer, while the USA is the lowest. China and the India have been switching between third and second position after the Middle East.

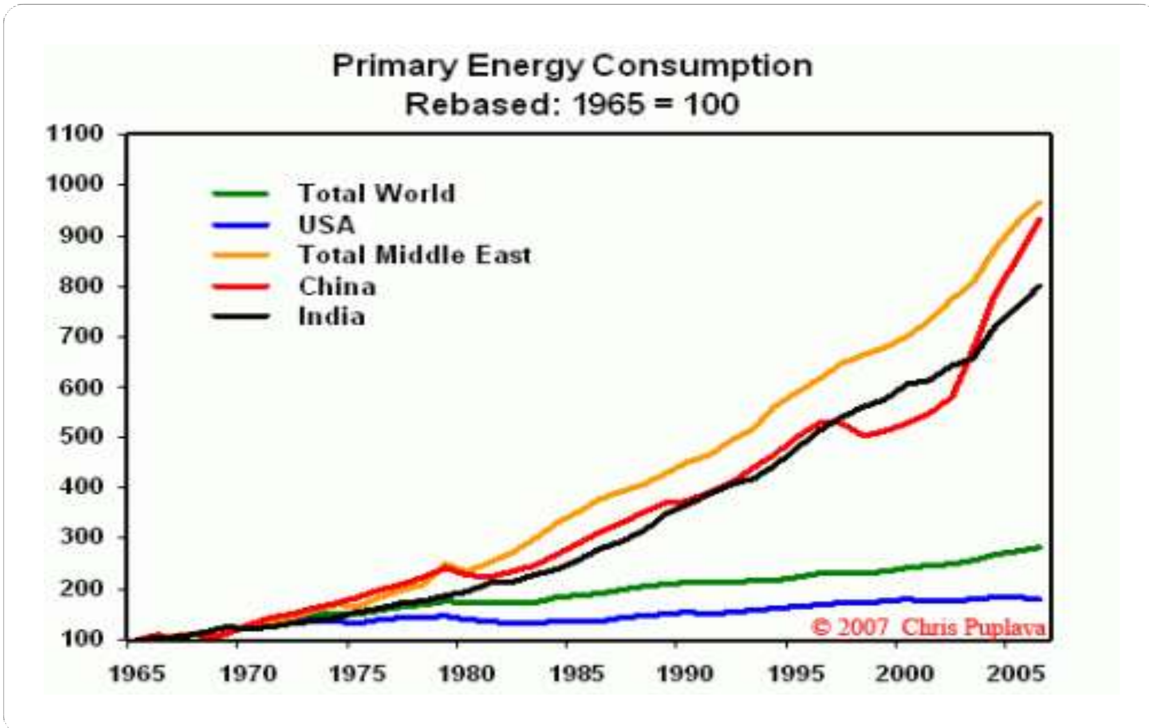


figure 2- 2 (Source: BP Statistical Review of World Energy 2007) Accessed 14/01/17

Figure (2-2) above is a clear indication of the energy consumption in the Middle East in comparison to other countries in the world, with the Middle East countries being ranked as amongst of the highest consumers of energy. According to the diagram, the middle East is the highest, showing a significant increase from 1965 of 100 (TWh) to as high as 1000 (TWh), a tenfold increase, by 2005. In 1965, the diagram shows essentially the same levels for all the countries including the USA, China, India, and the rest of the world at 100 (TWh). China and India have continuously been increasing in consumption, though the Middle East remains the highest globally. It is interesting to note that even though the total world energy consumption (which include all the countries in the world) gradually increase from 100 (TWh) to approximately 280 (TWh) in 50 years it is still lower than the total energy consumption in the middle east which comprises only 18 countries. The breakdown could be summarised as follows, if the total energy consumption for 18 countries in middle east is 1000 (TWh) then the average consumption for each country would be 55.55 (TWh). On the other hand, if the total world energy consumption is about 280 (TWh) for 195 countries which means each country consumes 1,02 (TWh).

In comparison to global consumption, which reflects a decrease in energy intensity by 1.2% between 1990 and 2010, the Middle East energy has continued to rise considerably (Bahgat, 2013). Factors that influence energy consumption, like low energy prices, have been shown to result in widespread overuse of energy and wastage (ibid, 2013). The Middle East has shown a reliance on energy-intensive industry, such as Petro-chemical and aluminium, as well as using techniques like gas flaring and gas production, which also contribute to energy increase. These are worsened by energy intensity lifestyles in buildings and transport, which can be attributed to low energy prices, and the transmission and distribution losses in power systems.

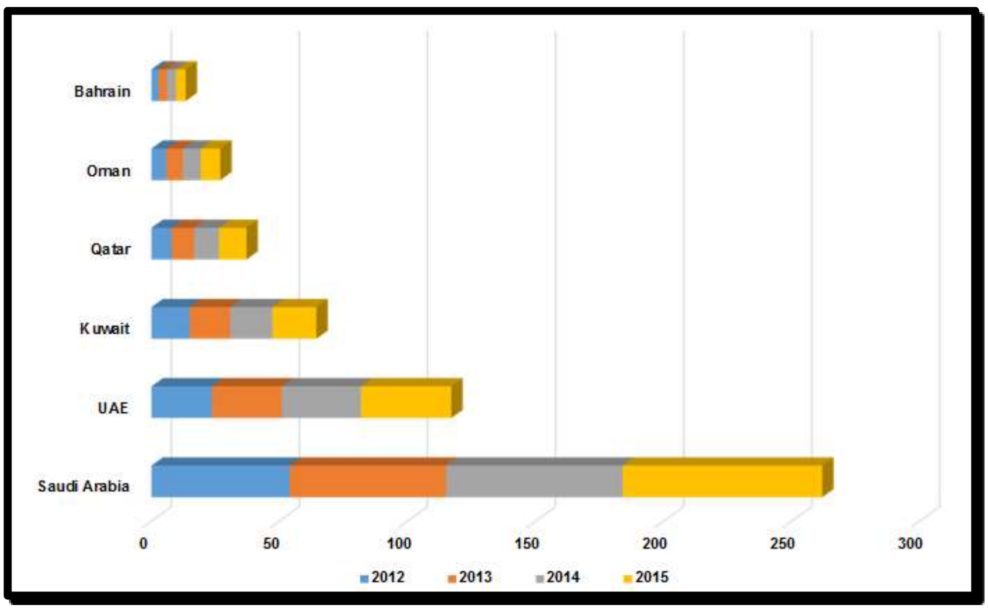


figure 2- 3 Power generation capacity in the GCC by country, 2012 -2015. (source: https://www.grandviewresearch.com/research-insights/gcc-protective-relay-market-increased-electricity-demand-to-drive-growth) Accessed 14/01/17.

Figure (2-3) above is a demonstration of the energy used in generating electricity in the Gulf Cooperation Council (GCC) countries. According to the diagram, Saudi Arabia was the highest consumer for all years from 2012 to 2015. This shows that while the Middle East has been identified globally as the highest consumer of energy, Saudi Arabia can be singled out as the highest consumer of energy among the Gulf countries. This diagram reveals the issue of energy consumption and that, unless measures are taken to rectify this, the problem will continue to spiral even higher.

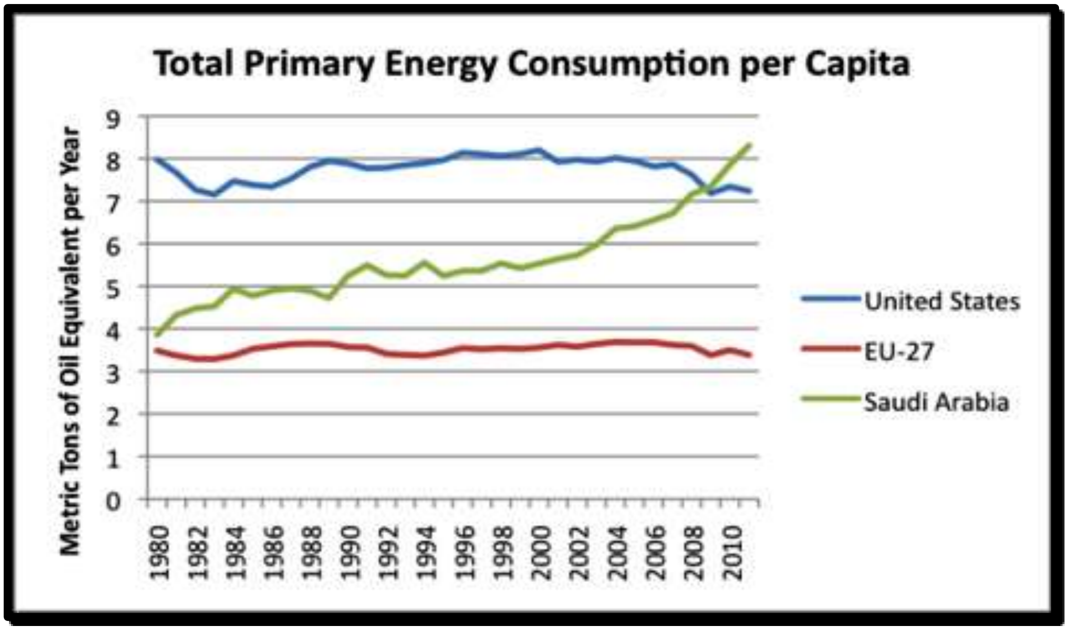


figure 2- 4 Total primary energy consumed per capita, based on BP's 2012 Statistical Review of World Energy data and population data from EIA.

Global energy consumption increases occur because of irresponsibility or ignorance regarding the subject. In the 1930s, the need for water resulted in King Abdul-Aziz AL Saud requesting assistance from an American geologist, which led to oil being discovered. Because of this, the Gulf countries rapidly progressed from being underdeveloped and underpopulated to being the largest suppliers of oil worldwide. The oil boom enabled the social and economic transformation of the Gulf countries, like Bahrain, Kuwait, Oman Qatar, Saudi Arabia, and the United Arab of Emirates (UAE) which became global leaders in oil and natural gas production and among the top ten energy consumers (Volk, 2015). The idea behind the mass production of oil was to invest in technology that would enable the generation of water supplies, resulting in considerably higher energy usage.

One of the determinants of energy consumption is the population boom resulting from exceptionally high birth rates and large-scale immigration. These factors have increased the population from 8 million in 1971 to 45 million in only 40 years (Al Attiya, 2015). In addition to this population shift, the local climatic conditions also contribute to levels of energy use, with residents seeking comfort by modifying the temperature of their homes.

In comparison to all six countries in the Gulf, Saudi Arabia energy consumption is especially high (Al-Shehri, 2008) comprising more than half the country's demand. The discovery of oil and the spread of popularity of Saudi Arabia globally resulted not only in its increased influence within trading grounds, but also to improved individual lifestyles as the government distributed the wealth of the country to benefit its citizens. This resulted in electricity becoming a subsidised product, though this practice has since been ended.

During this period of subsidised energy, the populace showed a distinct lack of individual motivation to save energy, hence figures continued to increase. While the country benefited from the global influence economically, it can be argued that the adoption of certain aspects of global culture has had adverse effects on Saudi society, such as the changes to the architectural sector brought about by Western styles and immigration.

Electricity Generation Comparison for The Six GCC Countries (TWh)

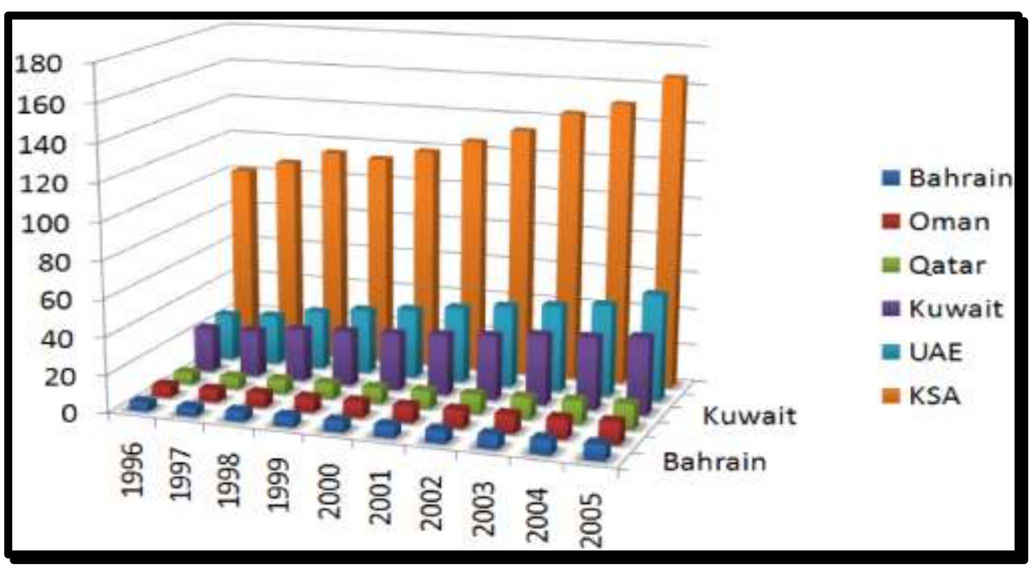


figure 2- 5 Electricity generation comparison for the six GCC countries (Source: http://www.mdpi.com/1996-1073/2/41201/htm) Accessed 14/01/17.

In comparison of how much energy Saudi Arabia uses to generate electricity compared to other GCC countries, Saudi Arabia has had the highest from 1996 to 2005 with figures of 100 (TWh) in 1996 while all other five countries combine used up to about 40 (TWh), an average of about 8 (TWh) for each country. It should be noted that even within Saudi Arabia several sectors contribute to the increase in the usage of energy for example the building sector as referenced by (Alshehri, 2008) consumes as high as 80 % while 53 % is attributed to residential buildings. In addition, industrial, commercial, governmental, and agricultural sectors use as much energy as 18 %, 12 %, 11 % and 2 % respectively. The sectors differ when focusing on each household for example (Alaidroos and Krati, 2015) assert that air conditioning is the highest consumer of energy with 72 % while water heating uses only 4% and 5% for lighting and appliances use up to *14 %.* Therefore, this research aims to determine the impact of *mashrabiya* on residential building energy performance in Saudi Arabia particularly Jeddah city with the hope of resolving the issue of energy usage and extending this to the entire cities with the same climatic conditions.

2.2.3 Building Energy Consumption in Saudi Arabia

Traditional buildings in Saudi Arabia are climatically responsive (Kamal, 2014). This statement supports the effectiveness of traditional buildings which utilised *mashrabiya* and other features in the construction to maintain indoor environmental quality. According to (Noble, 2007) traditional buildings used natural technologies such as fire chimneys, courtyards, wind towers and *mashrabiya* to control indoor environmental quality. Therefore, a gradual shift from traditional architecture to contemporary design indicates the adoption of inefficient, or at least less efficient, energy designs, causing a continual increase in energy consumption. One of the major causes of the increase in energy consumption in Saudi Arabia is housing, fuelled by industrialisation and economic development, as well as the effects of population growth and the climate. Due to the issue of the continuous rise in energy usage in Saudi Arabia, 2010 signified a major change as the government introduced Saudi Energy Efficiency Centre (SEEC) which aimed at fulfilling the future plans of implementing sustainable buildings in consideration of a sustainable environment.

The government in collaboration with Saudi Electricity Company (SEC) made two major decisions in regard to the awareness, and responsibility in the usage of electricity in residential buildings by stopping subsidy and increasing electricity tariffs which made residents more aware on the usage of electricity.

Table 2- 1 The differences in tariffs before and after the changes in 2018 in residential buildings

Pre- 2018 **household consumption segments**	**Post- 2018** **household consumption segments**
1 (1 – 2000) kWh = 5 halla	**1 (1 – 6000) kWh = 18 halla**
2 (2001 – 4000) kWh = 10 halla	
3 (4001 – 6000) kWh = 20 halla	
4 (6001 and more) kWh = 30 halla	**2 (6001 and more) kWh = 30 halla**

Table (2-1) shows electricity in kilowatt hours (kWh) and the amount residents paid for each tariff before and after the increase in electricity tariff in 2018. The amount of electricity differs for each household depending on its size and number of occupants. Some residents in Saudi Arabia have illegally installed two or more-meter boxes where each meter ranges between (1-2000) kWh and the amount paid is 5 halla, resulting in the total amount being 15 halla for three-meter boxes. However, in the new tariff, the residents pay up to 18 halla for each meter which totals up to 54 halla for three-meter boxes, a difference of 36 halla between the two. It should be noted that all the figures recorded above exclude taxes.

Figure (2-6) below shows the calculations for the new tariff which starts from the meter consumption per kilowatt-hour multiplied by current household consumption segments, giving the total amount in SR. Onto this total, 10SR is added which is the monthly counter charges followed by 5% VAT, with the overall outcome the value of the new electricity bill.

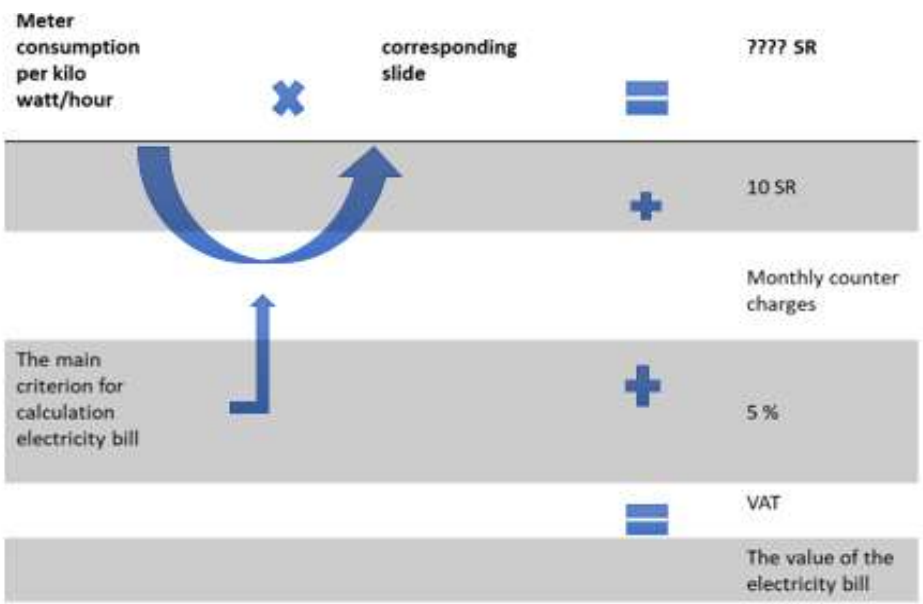


figure 2- 6 the calculations for the new tariff

Table (2-2) below is a representation of the total expenditure of energy consumption before and after the increase in tariffs. It is clear from the table that there is a substantial increase in the amount paid by residents for 500 kWh on energy consumption before and after the changes in the tariff, as shown by the table (2-2), of 200%, from 35 to 105 SR. According to the information provided by the interviewees, the majority of them use up to 2000 kWh, which is the highest total increase in percentage of (235.18%), as reflected by the data below.

Table 2- 2 High percentage of electricity bills for the residential sector in 2018

Before SR	Energy consumption kWh	Now SR	% of bill increase 2017 and 2018
35	500	105	200.00 %
60	1000	199.5	232.50 %
110	2000	388.5	235.18 %
210	3000	577.5	175.00 %
310	4000	766.5	147.26 %
510	5000	955.5	87.35 %
710	6000	1144.5	61.20 %
1010	7000	1459.5	44.50 %

Figure (2-7) below is a representation of the sharp growth in population from nearly 24 million people in 2007 to around 32 million in 2015, a total increase of almost 10 million people.

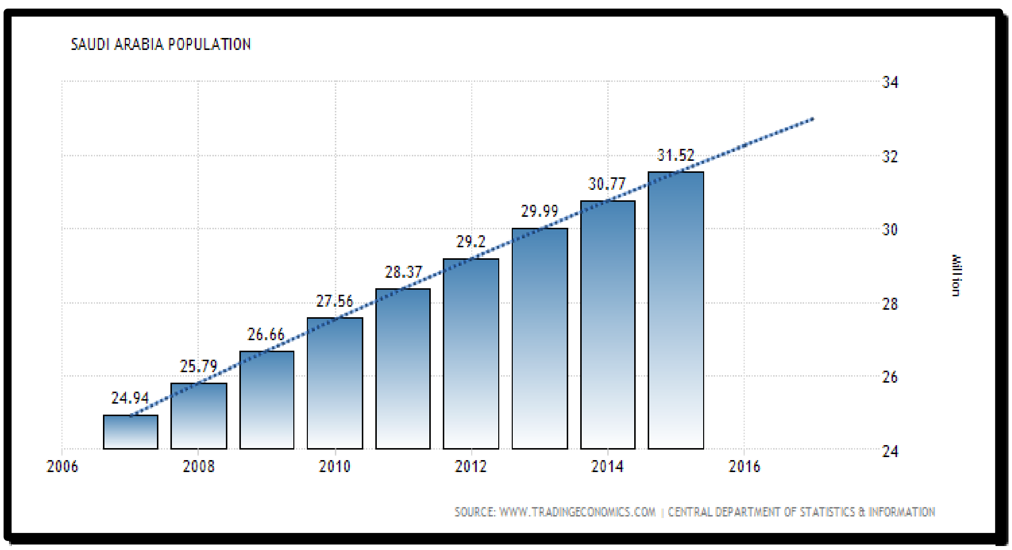


figure 2- 7 Saudi Arabia Population. (Source: Tradingeconomics.com/ Central Department of statistics& Information) Accessed 10/11/16

Several researchers have identified all the stated factors including shifting from traditional to contemporary style, climate condition and increase in population however stress that housing as well as certain aspects of buildings are contributory factors to the continuous growth of energy usage in Saudi Arabia. According to (Al-Shehri, 2008) buildings have contributed to 80% of the additional energy loss.

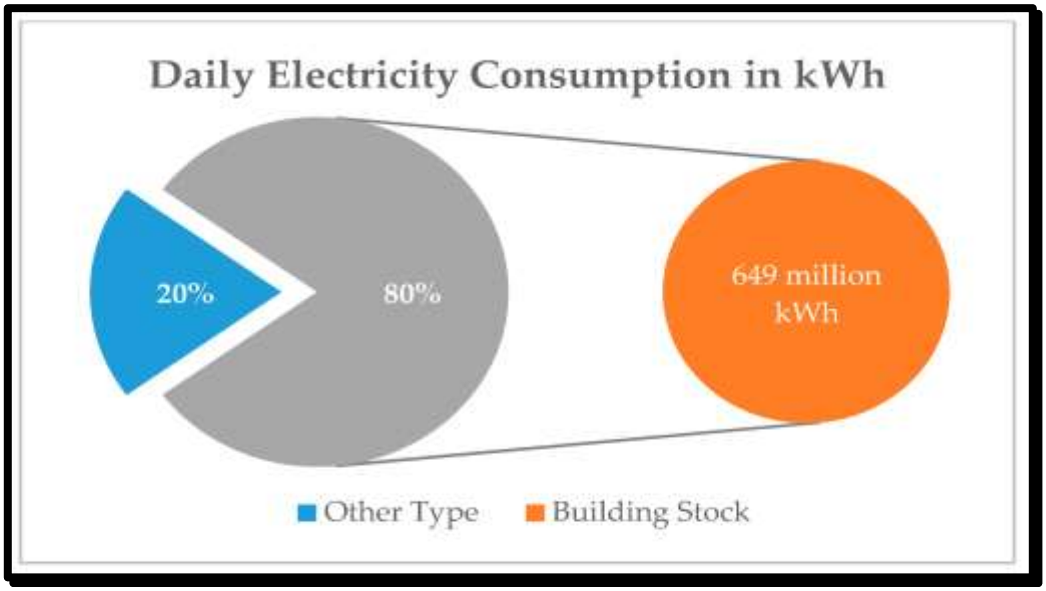


figure 2- 8 Electricity consumption in the building sector. (Source: Felimban 2019)

In addition to the impact of poorly designed buildings, where this loss can also be attributed to the use of air conditioning and refrigeration, which accounts for 70% of all residential energy use (Akbari, Morsy and Al-Baharna, 1996). The growth in population that has resulted in the need for more buildings in Saudi Arabia can also be directly associated with a higher demand for energy.

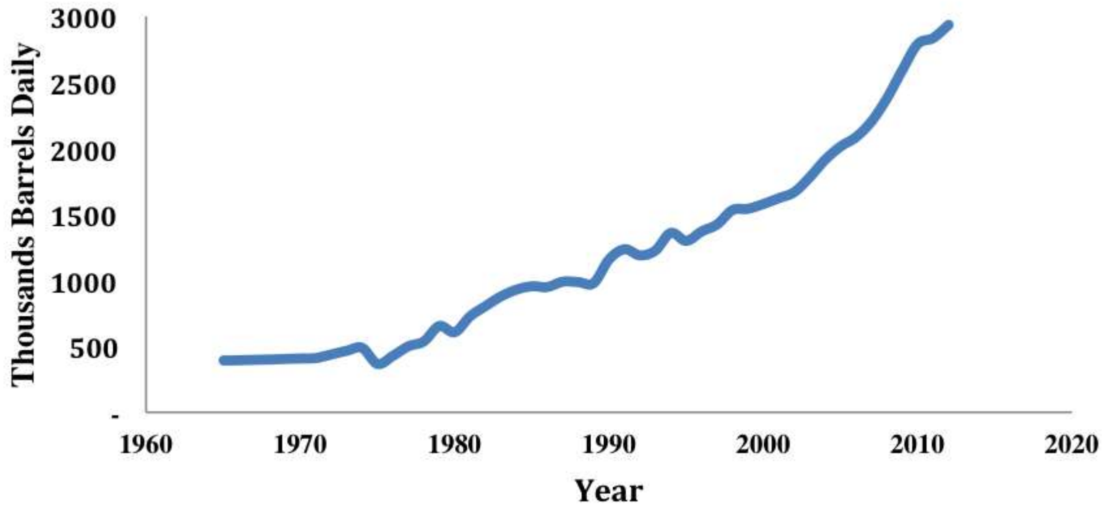


figure 2- 9 Saudi Arabia Domestic Energy Consumption (source: http://large.stanford.edu/courses/2014/ph240/aljama1/images/f1big.png)

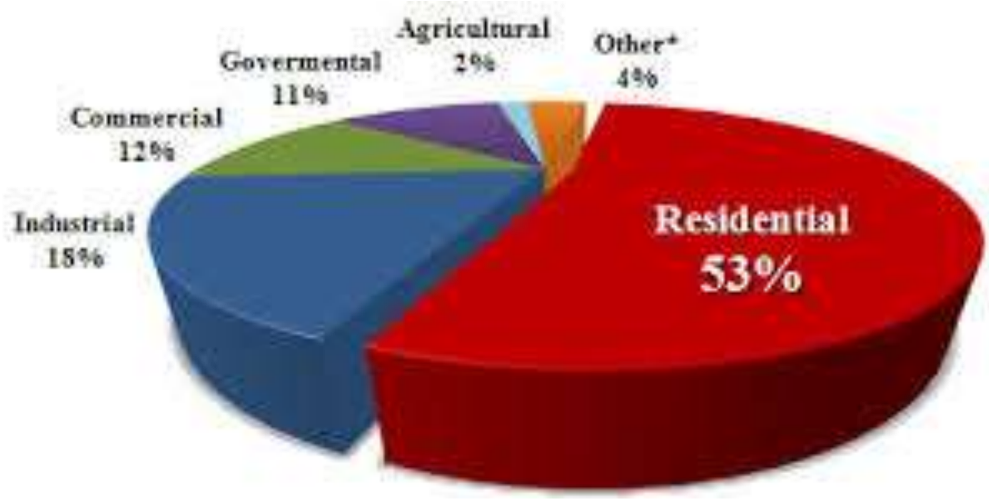


figure 2- 10 Saudi Arabia residential sector energy consumption compared to another sector (Source: Al-Ghamdi, Alshaibani (2017)

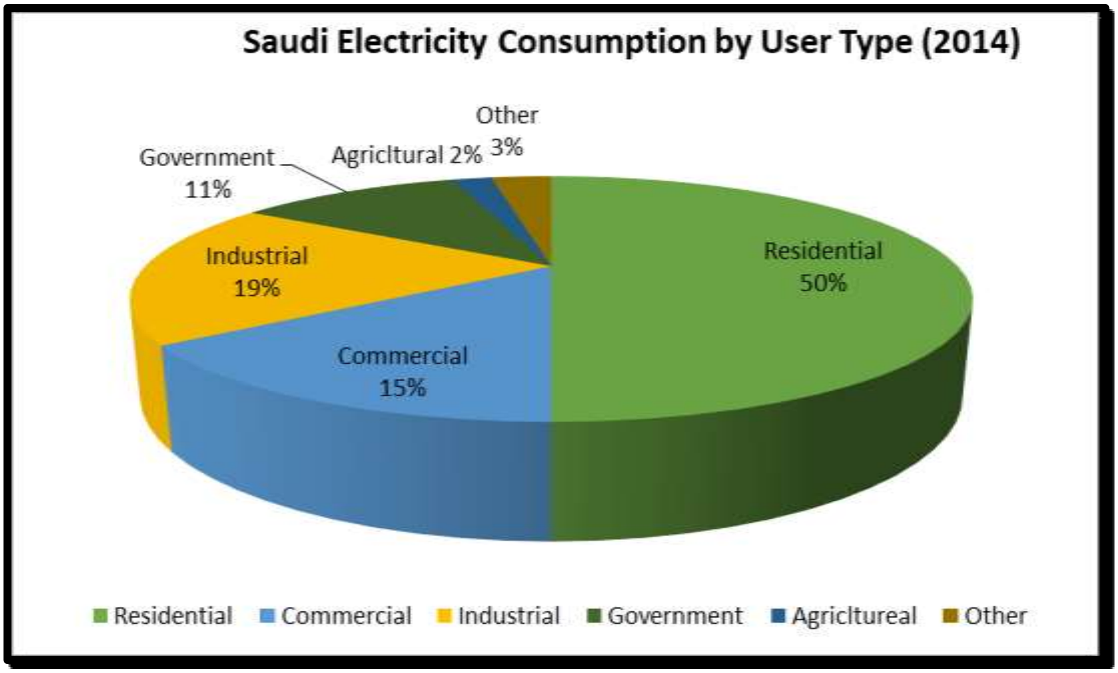


figure 2- 11 Saudi Electricity Consumption by user type (2014). (Source: SEC. Annual Report)

According to the pie chart above, residential buildings in Saudi Arabia use up to 52% of all energy (Alaidroos and Krarti, 2015), much of which is used for air conditioning (Al-Saadi and Budaiwi, 2007) as a result of the extreme local environmental factors. In addition, architectural development also plays a major role in the consumption of energy, with many structures using energy inefficient materials (Numan, Almaziad and Al-Khaja, 1999). As the population increases, the demand for energy consumption is also rising (Al-Saadi and Budaiwi, 2007) leading to a corresponding need for higher levels of energy. These three main factors are not an exhaustive list of issues resulting in unnecessarily high levels of energy consumption; however, they will inform the subsequent discussion of the architectural challenges facing Saudi due to its location population, climatic conditions and the architectural designs that are currently popular.

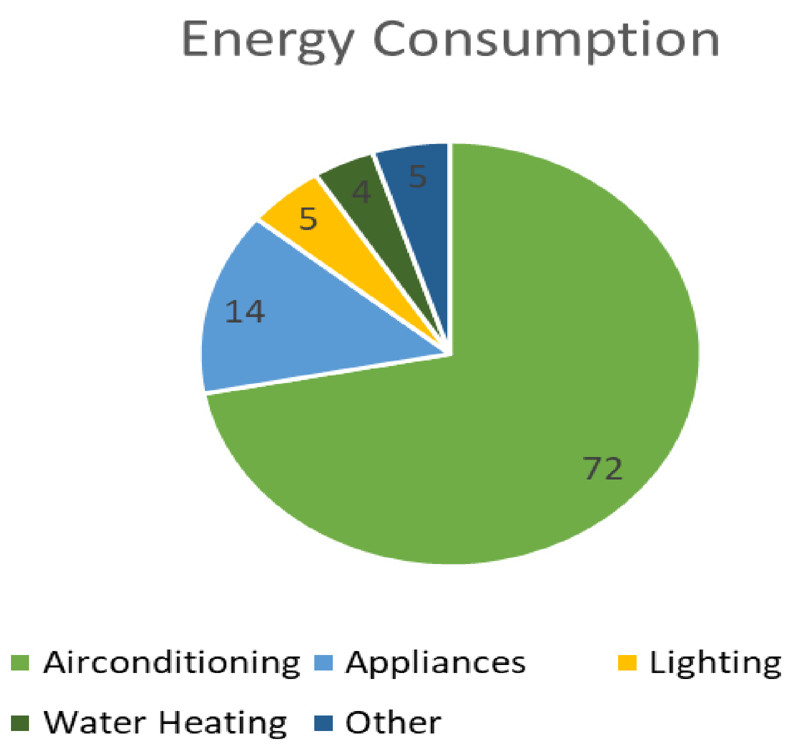


figure 2- 12 Air Conditioning percentage. (Source: ALAIDROOS and KRARTI 2015)

According to the pie chart fig (2-12) above, residential buildings consume as much as 72% for air conditioning which is the highest as shown on the diagram. On the other hand, water heating consumes up to 4% and is the lowest. The diagram shows the amount of energy consumed for lighting like the other devices a total percentage of 5. The second highest energy usage include 14% for the appliances.

2.3 Architectural Elements Affecting Energy Consumption in Buildings from Previous Studies

Energy consumption is dependent on the characteristics of the building and the occupant behaviour (De Dear, 2004; Moujalled, Cantin and Guarracino, 2008). Another factor may also include household size and age of occupants, as well as the building size (Blom, Itard and Meijer, 2011; Aldossary, Rezgui and Kwan, 2014). An increased number of residents may result in high demand for the use of facilities in a home, which may mean the use of electricity and therefore an increase in energy consumption. This latter point is important as Saudi houses typically have much bigger rooms than is typical in the rest of the world, leading them to show a consistently higher consumption in terms of air conditioning (Taleb, 2011). In simple terms, bigger buildings require more energy to cool their indoor environments.

The term ‘energy consumption’ can be further defined by intellectual factors like attitude and motivation to save energy (Andersen et al., 2009; Schweiker and Shukuya, 2009), with the national electricity subsidy many individuals have little motivation to reduce their energy consumption. The fact that residents get benefit for their electricity bills lessens due caution and responsibility with regard to saving energy. This is supported by (Taleb, 2011), who reiterates that due to subsidised electricity most individuals lack motivation to save energy. This means that people use energy with no consideration for the associated impact, as there was no practical reason from their perspectives to conserve energy.

The Kingdom of Saudi Arabia has experienced a continuous increase in energy consumption, which has resulted in considerable research being carried out to determine the causes and provide solutions. A vast number of researchers unanimously agree that the usage of energy in the country has reached an undesirable level, and which will almost certainly have a negative effect in the future. Although these authors agree that energy increase is an issue, they mention different factors that contribute to the same outcome. For example (Alitany, 2014) highlights climate while (Akbar, 2012 cited in Sidawi, 2012) asserts that economic wealth was a major cause which led to the movement of people from the village to the city. This issue of energy consumption has divided opinion in the academic world. Researchers point out three major causes for the energy increase, namely buildings, climate, and population. (Aljamea, 2014; Taleb, 2011) are of the opinion that population is one of the factors which contributed to the increase in energy consumption as this led to the demand in housing where (Kamal, 2014) states that this also resulted in the shift from traditional to contemporary style as architects adopted western features and techniques which led to the increase in energy consumption. There are further investigations as detailed information below provided shows what elements of the building and the results in the investigations.

Figure (2-13) below is a summary of factors that impact on energy consumption from previous studies. It shows three main factors including building elements, climate condition and population. In the diagram, the population increased as a result of migration, internal movement and child boom. In addition, the building elements which have an effect on the increase in energy consumption comprise wall, roof, thermal insulation and window and the shading device. In conclusion, although energy consumption is a global issue and has been explained by the impact of factors as diverse as location, population, and country development.

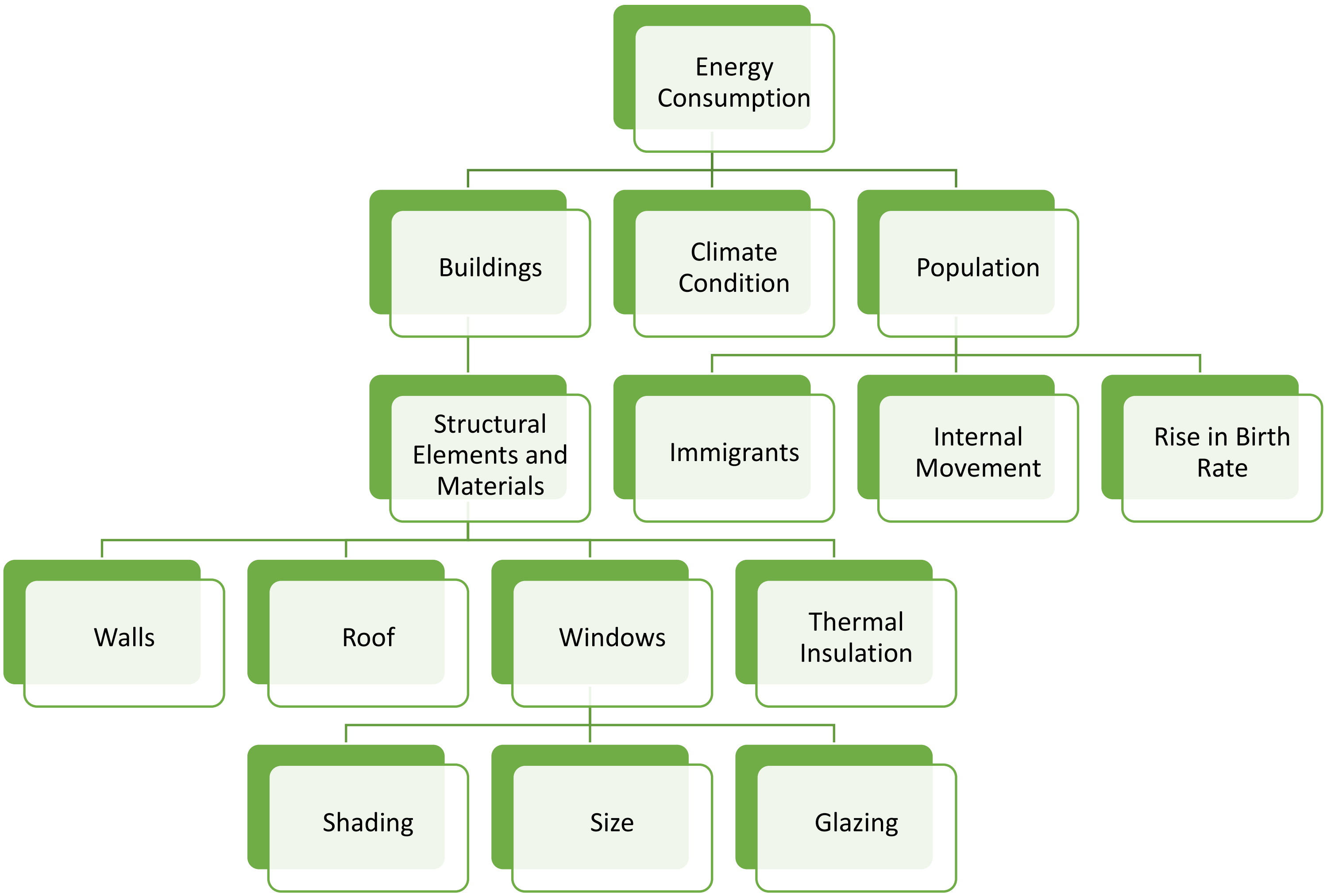


figure 2- 13 Factors that affect energy performance in Saudi (Source: Alghamdi 2017)

2.3.1 Building Envelope

The major cause of the high increase in energy in the buildings in hot climate countries is due to their envelope design, certain elements of the buildings as well as its orientation have been more highly emphasised than others. It is well known that in any building's heat gain and leakage occurs due to thermal insulation, windows, walls, roofs, and doors. (Alaidroos and Krarti, 2015) confirm that residential buildings in Saudi Arabia contribute to 52% of the KSA's total electricity consumption. (Al-Jamea, 2014) corroborates the fact that 80% of electricity is lost due to poor building design, while (Kamal, 2014) emphasises that such buildings contribute to uncontrolled energy consumption. In terms of buildings, various research studies have focussed on residential buildings, particularly in terms of an appropriate thickness of thermal insulation and whether this is located on the external or internal surfaces of the building. (Saleh, 1990) not only researched thermal insulation in terms of 5, 7 and 10 cm thick samples but also with regard to location around the building. The results showed an appropriate combination of the use of air conditioning and thermal insulation in the interior. In relation to the wall thickness, a thickness of 5-10 cm proved effective in terms of energy performance when located on the outside layer of the exterior wall.

- ***Roof***

As the most important architectural elements that can provide indoor comfort, the walls, roofs, floors, and windows can be contributory factors to a rise in energy usage. (Al-Sanea, 2002) determined the effectives of the types of roofs and the materials used in their construction from a sample of size types of roofs in Saudi Arabia. The simulated results showed much better energy performance compared to uninsulated roofs. The reductions revealed a 32% saving using a 5.0 cm thickness of moulded polystyrene insulation, 27% for extruded and 22% for polyurethane insulation of 5 cm thickness.

- ***Walls***

Dealing with the issue of building envelopes, would result in less energy consumption. While researchers identified walls as problematic to energy increase, a few researchers have further focussed on not only the type of construction materials used for walls but also the thickness of such in an attempt to examine how to reduce soaring energy consumption figures. (Abdelrahman, Said and Ahmad, 1993) note that not only are walls a cause of concern however, investigated further into the use of thermal insulation on different types of thickness of the wall and the location. The investigation focussed on concrete blocks and clay bricks, finding that clay bricks require less insulation than concrete. In addition, (Al-Sanea and Zedan, 2011) also investigated energy performance with regard to wall thickness and location in the city of Riyadh. The research included walls with various layers, one, two and three places in three positions the middle, externally and internally. (Al-Sanea, Zedan and Al-Hussain, 2013) further researched various types of masonry materials from four samples, namely clay bricks, concrete, sand lime bricks, and prefabricated walls with a 0-50 cm thickness. It was found that clay bricks allowed for a reduction in energy consumption by 16% in comparison to concrete bricks, the sand lime showed 23% and finally 25% with prefabricated walls.

- ***Thermal insulation***

Thermal insulation has been implicitly performed by individuals backdating from the cave period to highly insulated houses in the 21st century (Bynum, 2001). (Bynum, 2001) goes on to list several materials one might associate with good thermal insulation such as animal fur, bird feathers, cotton, wool, straw, and human hair. While humans have historically used all these as protection against climatic conditions, they have also built homes using wood, stone, mud, and other materials to provide protection against extremely hot and cold weather conditions. Historically, the importance of thermal insulation spread globally with an emphasis on materials which were selected dependent on location and the climatic conditions for the particular country. In an attempt to retain heat, cork was used on shoes for the purposes of warmth, cork was mixed with clay for houses, straw and clay for walls, dried sea grass for walls and roofs, etc. (Bynum, 2001). Table 6 shows various types of insulation used in the past in different countries to serve the same purpose for various architectural elements of buildings.

Table 2- 3 created by Alghamdi; S. (2019) adapted from Bynum (2001)

Nationality /Country/people	Type of insulation	Reasons/Use
Ancient Greeks and Romans	Asbestos	Used for its resistance to heat and fire
Romans	Corks	Used for insulation in shoes to keep feet warm
Early Spanish habitants	Cork bark	Stone houses were lined with cork barks
Egyptians	Earth	Subterranean chambers and grottos in hot days
Pliny	Cork	For insulating roofs
North American natives	Cork mixed with clay	For walls
European huts	Woven straw with clay	For walls
South seas	Sea grass	Built huts

It was actually only in the 19th century that thermal insulation gained general public awareness, resulting in further investigation in the use of lighter materials to both retain and repel heat. According to (Bynum, 2001) heat is gained during the summer and lost in the winter. However, the role of insulation is to ensure indoor environmental quality is maintained, i.e., to regulate temperature. In order to achieve indoor environmental quality, the various mechanisms of heat energy transfer convection, conduction, and radiation – need to be properly considered.

(SCECO Electrical Affairs Agency (EAA, 1995), recommends the use of various types of thermal insulation in Saudi Arabia such as the ones listed in the table below.

Table 2- 4 Types of thermal insulation used in KSA.

Insulation Material type	R- Value (M^2.k/W)	Environmentally friendly	Commonly used for	Note
Polyurethane / Polyisocyanurate foam	**R 6.3**	**No**	**sidewalls**	**high insulating efficiency and density, low water permeability**
Polystyrene extruded and expanded	**R 4.0**	**No**	**roof and wall insulation**	**low thermal conductivity and water absorptivity**
Fiberglass	**R-3.1**	**Yes**	**AC ducting systems**	**low thermal conductivity**
Mineral fibre	**R- 3.1**	**Yes**	**roof and wall insulation**	**low thermal conductivity.**

- ***Windows***

Windows are one of the major factors in the controlling of the indoor indoor environmental quality' as stated by (Wei, Buswell and Loveday, 2013). In addition to that (Herkel et al., 2008) in (Wei, Buswell and Loveday, 2013) believe that the percentage of the opening of the window is determined by the outdoor temperature. (Al-Saadi and Budaiwi, 2007) claim that residential buildings are major causes of rising energy usage in Saudi Arabia, contributing to more than 51%, but also further pinpoint that more than 70% of this usage is due to poor envelope designs such as in the walls, roofs, and windows, as also noted by (Abdelrahman, Said and Ahmad, 1993). Accordingly, they investigated on the effects of various materials, but particularly the types of glazing used in Riyadh and Dhahran. The research showed that double glazed windows result in significant energy reduction in hot climates. Similarly, (Aldawoud, 2013) focussed on the types of glazing used in windows and extended his research to shading in Riyadh using appropriate simulations. (Aldawoud, 2013) concluded that double glazed windows and shading can contribute significantly to reducing energy usage.

Most researchers have identified double glazed windows as being effective at energy saving; for example, (Aldawoud, 2013) concluded using simulation that double-glazed windows are effective in energy reduction.

- ***Shading***

Shading devices can be used for several reasons as mentioned by (Steemers and Yannas ,2000) that they reduce solar gain by blocking the sun rays which can be transmitted into the indoors and allow acceptable lighting this also enhances indoor environmental quality which results in reducing energy consumption. (Mandlaki and Tsoutsos, 2019) describe the functionality of shading devices which include.

- Provide indoor environmental quality by reducing solar gain and average temperature.
- prevent direct sunlight over the occupants to reduce sun burn.
- Reduce the glare which may result in high temperatures and discomfort to residents.
- Minimise sunrays and promote indoor environmental quality.

While shading devices can be used for protection against solar gain others can also be used for aesthetic purposes. According to (Givoni, 1994) shading devices can be categorised into two major groups including fixed and adjustable. In addition (ibid, 1994) further divides the shading devices into external and internal where external devices include shutters, hinged, sliding and venetian blinds while internal shading devices include venetian and roller blinds as well as curtains and blackouts. The shading devices can be made of wood, fabrics, asbestos and metals. The Energy and Resources Institute (TERI, 2004) provide examples of fixed shading devices such as the vertical and the horizontal.

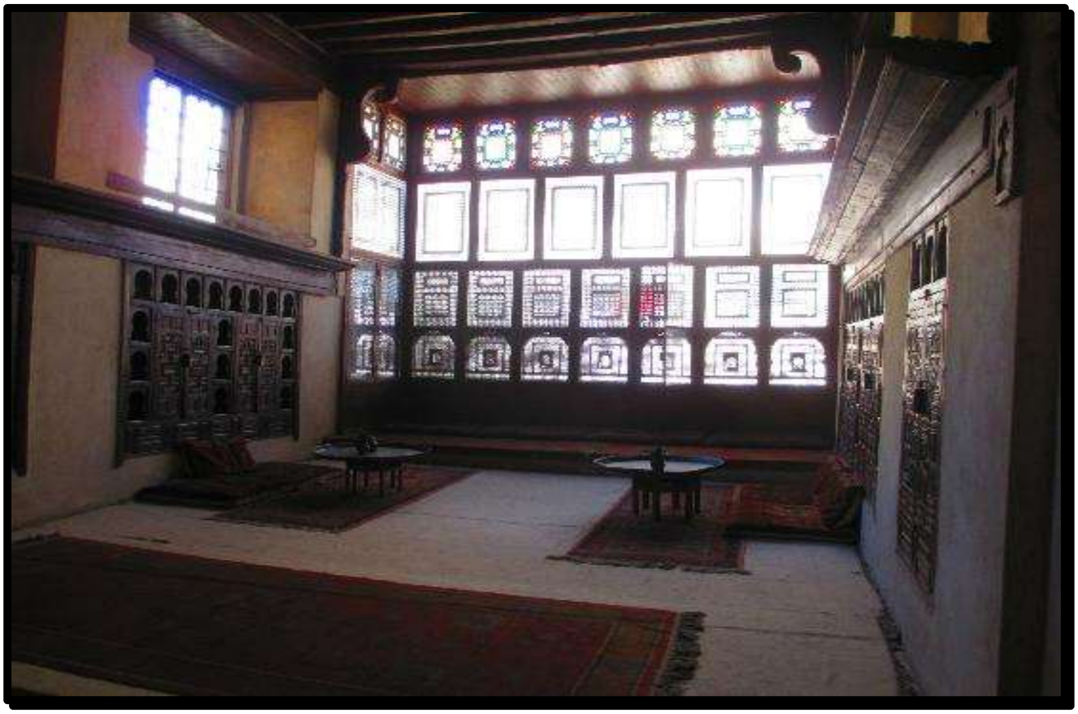


figure 2- 14 Traditional window Alsuhami house Egypt (Mashrabiya) (Source: Google Maps 2019).

As a shading device *mashrabiya* have proven to be effective over the years; during the Ottman Empire, they were used to provide natural ventilation, light, and allowed for -used for large openings to ensure air regulation and privacy. This shading device was traditionally used for several purposes such as the provision of natural light, air, identity, and privacy as stated by (Aksamija, 2015). This the main reason for the research to find out if reinstating *mashrabiya* due to its functionality can have impact on building energy performance while providing privacy and architectural identity. Not only can *mashrabiya* be useful in the reduction of energy, (Steel cited in Aksamija, 2015) asserts the regulation of air as well as reduction in heat and of solar radiation.

Causes and effects of the use of large glass windows.

Table 2- 5 Causes and effects of the use of large glass windows.

<table>
<tr><td rowspan="6">Modern Architecture Style</td><td rowspan="6">Caused</td><td rowspan="6">Residents to use large glass windows.</td><td rowspan="6">Resulted in</td><td colspan="9">Loss architectural identity</td></tr>
<tr><td colspan="3">Absence of natural lighting</td><td rowspan="3">Caused</td><td rowspan="3">Darkness, Absence of natural lighting</td><td rowspan="3">Resulted in</td><td rowspan="3">Use artificial light</td><td rowspan="5">Increase in Energy Consumption</td></tr>
<tr><td>Glare</td><td rowspan="2">As a solution</td><td rowspan="2">Residents used window shading.</td></tr>
<tr><td>Lack of Privacy</td></tr>
<tr><td>absence natural ventilation</td><td rowspan="2">Caused</td><td rowspan="2">Discomfort in indoor environmental quality'</td><td rowspan="2">Resulted in</td><td colspan="3" rowspan="2">More use of AC</td></tr>
<tr><td>Heat gain</td></tr>
</table>

- ***Building orientation***

A number of researchers have considered the relationship between building energy performance and its orientation. According to (Nasrollahi, 2012) there is a significant correlation between energy consumption and building orientation. Further, (Karaj, 2013) highlights that building orientation can influence heating, cooling, and lighting energy demands. (Karaj, 2013) goes on to suggest that the effort exerted in changing the orientation of the building may have a significant impact on energy consumption.

The stereographic diagram is a representation of the sun paths in Jeddah. This diagram enables architects to make informed decisions on the suitable shading devices in designing buildings. According to (Masoud, 2014) stereographic diagrams show the movement and positions of the sun in the sky daily and throughout the year. The movement of the sun, altitude and climatic conditions determine the intensity of solar radiation that each location receives which could be unfavourable to the building environment and more so the occupants. The city of Jeddah is located at latitude 21° 32' north, 39° 10' East 15 m (49 ft.). This can be clearly observed in Jeddah buildings which have the northern and western façade as the most effective orientations for buildings. Considering the sun movement, the Northern facades have no direct exposure of the solar radiation. This is followed by the western orientation which has minimum direct exposure of the solar radiation at the same time benefiting from the cool breeze of the red sea. However, the eastern and southern orientations are the worst due to extremely hot and longer periods of exposure to solar radiation particularly from the afternoon to sunset.

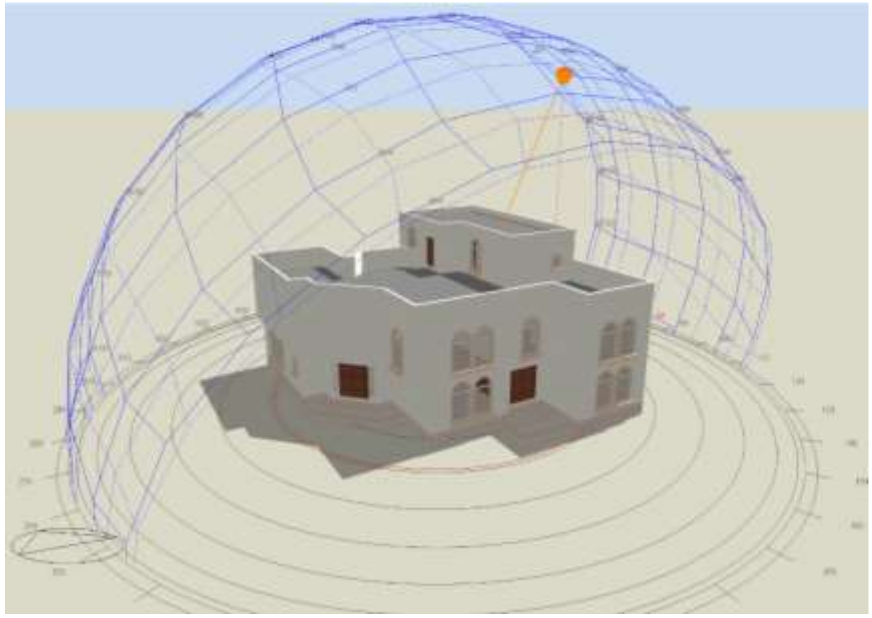


figure 2- 15 Building orientation (source: Alghamdi, S. 2019)

2.4 Social Cultural Aspect

2.4.1 Definition of Identity and Privacy

Identity and privacy are pivotal and inseparable concepts which are significant in the Hejazi architecture which is grounded on the Islamic architectural principles. These words if viewed from a general language point of view hold less weighting as in the context of the buildings in the Gulf region. While both these terms share a common value, the meaning slightly differs from an architectural perspective. According to (Lynch cited in Hojjatollah, 2012) architectural identity is defined as factors such as geometry, form, colour and more, which are important to enhancing the meaning of identity. In addition, three key principles are required in achieving Hejazi architecture, which include identity, culture, and environmental factors. (Othman, Arid, and Buys, 2015) view privacy as a safe and private personal place and family sanctuary.

2.4.2 Identity and Privacy

While identity and privacy may be viewed separately in terms of meaning, it is interesting how these concepts are intricately linked in relation to the shift in traditional architecture in Saudi Arabia. The factors that resulted in the diminishing identity in Saudi Arabia are also the same as those that led to the gradual reduction in privacy. The traditional buildings showed a clear distinction between private space for domestic purposes and open spaces for the community. According to (Saleh, 1990) the main purpose for this division was to ensure that residents experienced maximum visual privacy. The traditional buildings and residential layout promoted privacy in the form of narrow winding streets. The close arrangement of buildings which had their front façades facing away from the street still allowed for natural ventilation because of their orientation. (Saleh, 1990) also notes that transition in architecture from traditional to modern became evident in particular with the introduction of large glass windows which were supposed to provide attractiveness. However, this resulted in a lack of privacy as residents felt exposed to outsiders; due to this, these residents resorted to resolving the issue by introducing barriers or fences to increase their levels of privacy. Even though this provided a degree of privacy, it distorted the physical appearance or architectural identity of the city. The impact of the economic advancement became obvious as the local authorities responded to global pressure by gradually changing the image of the city to reflect a global image which adopted western styles hence the identity of the city gradually transformed.

figure 2- 16 The use of high fences and shutters to provide privacy (Source: Google Maps 2019).

It is the increase in the shift from the issue of identity which has been researched for several years by various researchers, such as (Kamal, 2014) who focussed on traditional architecture and sustainability, while (Akbar, 2012) researched the diminishing role of windows in traditional architecture, and finally (AL-Naim, 2008) majored on identity and local architecture from different perspectives. However, the general conclusions drawn reflected the fundamental truth of the gradual loss of the architectural identity in Saudi Arabia. This is reflected in the statement of bewilderment expressed by the residents about (AL-Naim, 2008) states that 'people have found themselves in a different physical environment due to loss of the identity of the city'. This unexpected change of environment resulted in conflicts not only between residents, but also divided opinions among researchers who drew conflicting conclusions as to the causes of the identity loss of the city. (AL-Naim, 2008) condemns one of foreign company which temporarily resided in the eastern part of Saudi Arabia for a few years and was responsible for town planning during its stay. During this period, employees are criticised for displaying even a trace of their own culture, which is now reflected in the newly built buildings. An expansion of the designs is spreading slightly as homeowners abandon the esteemed traditional style and adopting contemporary designs. It is evident that these changes resulted in cultural clashes as the majority of residents were opposed to the idea. The 'infiltration' of foreign design started in the eastern part of the country and gradually penetrated the west, where (Akbar, 2012) acknowledges foreign influence in the Hejazi architecture but further explains the negative impact of the media, particularly through watching American programmes which has influenced the thoughts of natives in terms of moving from traditional designs to a combination of both Western and Hejazi architecture.

figure 2- 17 ARAMCO's impact on architecture in the Eastern region (Source: Google Maps 2019).

2.4.3 Privacy and Islamic Architecture

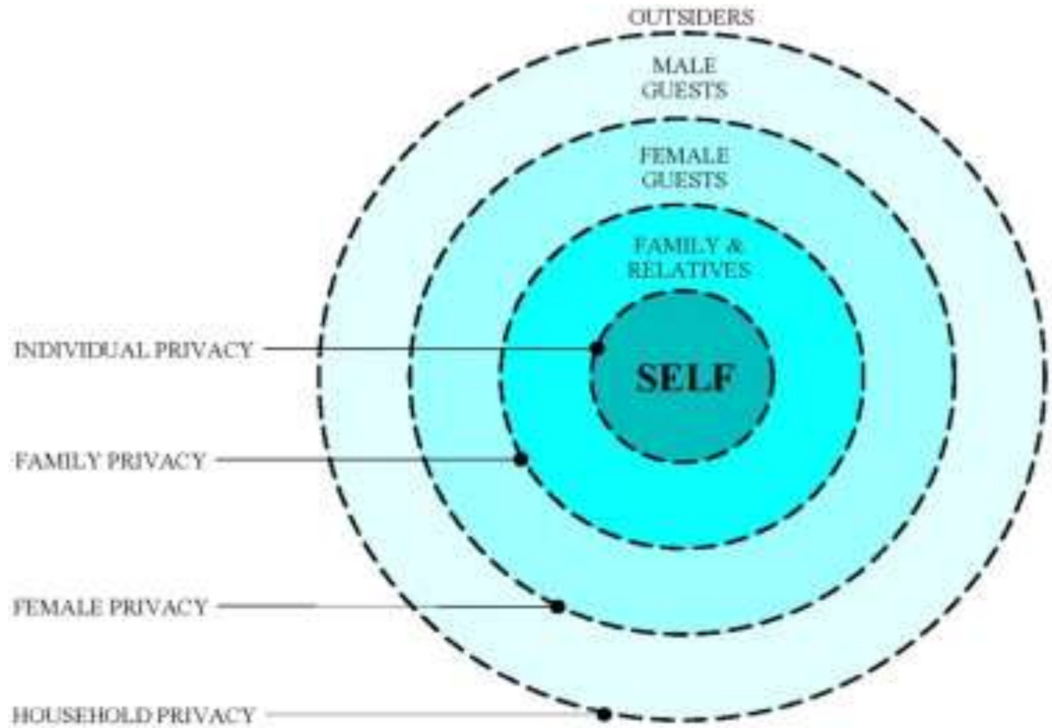


figure 2- 18 Five Layers of privacy in traditional Muslim homes (Source: Bahammam 1998)

Privacy is a term which has numerous meanings depending on the country, its beliefs, and its morals. In the Islamic world, privacy is closely connected to religion, hence (Othman et al., 2015) define privacy as a safe private place for personal sanctuary while (Bahamam, 1998 and Mortada, 2011) believe privacy, in the context of a traditional home, can be divided into various categories such as household, female, family, and individual privacy, as illustrated in the diagram above Figure (2-18). The goal of every individual home, according to (Daneshpour, 2011), is that visibility to outsiders is minimised; in traditional buildings, this was achieved by the use of wooden lattice screens or *mashrabiya*. The architecture of Saudi Arabia is influenced by religion in the organisation or utilisation of space, even though this is not clearly regarded as a standard. This is clearly noted in the use of female, male, private, and public spaces, as stated by (Goffman, 1959), who further states that the use may be for various functions, be they social or psychological in intent. (Abu-Gazzeh, 1994) blames the erosion of privacy on the mid 1970s era of the oil boom where the movement of people, because of global trade, contributed to a shift from traditional to modern architecture as expatriates and visitors settling in the country brought cultural traces of their own architecture into the country. (Abu-Gazzeh, 1994) reports that as a result of all this, cultural mix privacy in Saudi Arabia began to fade as the planning rules also relaxed, enabling immigrants to build in such a way as to reflect their own cultural designs. However, this also resulted in cultural clashes as more residents shifted away from traditional architecture. The loss of privacy in the country has become an issue of concern, resulting in the collaboration of intellects from various disciplines, including architects, urban designers, landscape architects and social scientists, to resolve or restore the lost privacy.

Figure (2-18) above summarises the levels of privacy as noted by (Mortada 2003 and Othman et al, 2015) which includes individual privacy, family privacy, female, and household privacy. The buildings are designed in a manner that values these forms of privacy. (Memarian et al., 2011) provide further explanation of the levels of privacy which include the aspect of visual privacy where an object is exposed and uncovered, hence its visibility. The second is acoustic privacy, which involves noise, and finally is olfactory privacy, which is odour control (Mortada, 2003; Sobh and Belk, 2011; Sobh et al., 2013) figure (2-18)

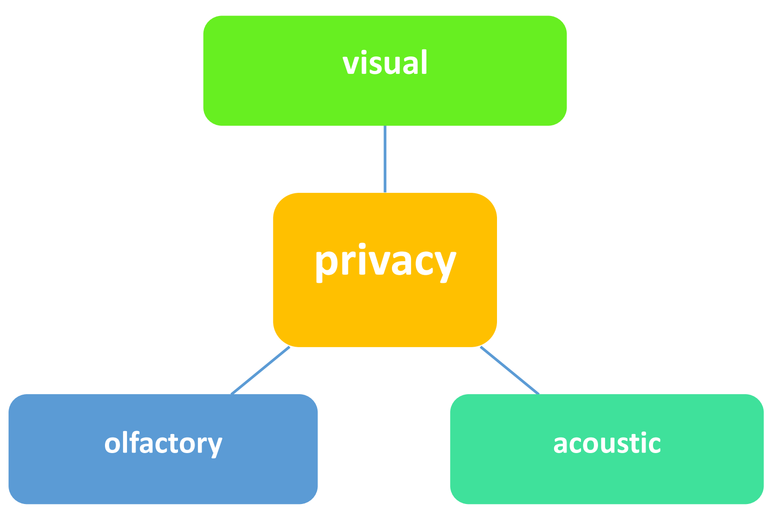


figure 2- 19 Categories of privacy in Islam

These categories also show the levels of privacy which can further be grouped into visual, acoustic, and olfactory privacy. According to (Sobh et al., 2013) olfactory privacy is defined as the control of smells or odours produced from cooking, which is why residents burn incense to neutralise such odours. In order to achieve or maintain this level of privacy, buildings are designed in consideration of both internal and external privacy which include the olfactory, visual, and acoustic.

2.4.3.1 Privacy and Architecture

The relationship between privacy and architecture can be seen in various architectural elements. For example, visual privacy can be maintained by focussing on the external part of the buildings such as the doors, windows, and the heights of buildings, while internally, the courtyard and gendered spaces between males and females should also be constructed in such a way as to promote privacy within the communities mentioned. Finally, acoustical privacy is also accomplished by paying attention to the external parts of the building including the roofs, walls, and floors, ensuring noise from neighbours is restricted. (Hakim, 1986) is of the opinion that acoustic privacy is achieved by thick walls. Additionally, (Mortada, 2011; Hakim, 1986) further state that these walls, which are made of mud bricks, stones and rocks that function as sound insulation in traditional buildings. At the same time, the walls are internally well insulated, preventing any sound entering the home. Olfactory privacy is achieved by treating the indoor air using incense.

2.5 MASHRABIYA

2.5.1 Definition of *Mashrabiya*

Mashrabiya is an architectural element which projects from a wide opening in facades of houses and is also historically designed to serve in physiological, environmental, social, and religious needs. Researchers define *mashrabiya* with each presenting a different aspect of this multifunctional architectural structure. (Othman et al., 2015) note that a *mashrabiya* is a lattice window structure or screen. It should also be noted that this lattice screen was designed from scraps of left over imported wooden material and that local architects designed and hand-made it.

figure 2- 20 Traditional architecture In Hejaz (Source: Google Maps 2019).

According to (Batterjee, 2010; cited in Hariri, 1991) a (R*oshan) mashrabiya* is an opening or vent in a wall. This definition devalues the multiple functions of *mashrabiya* as an air regulator and promoter of privacy to only a hole on the wall. In addition, (Fathy, 1986) explains that the name *mashrabiya* has its roots from an Arabic word, *mashrab*, which literally means a drink or a place for drinking. While *mashrabiya* are viewed in many functional aspects, (Fathy, 1996; Akšamija et al., 2015) also highlight the fact that it is a cultural icon serving both spiritual and decorative purposes. At the same time, (Mortada, 2003) sums up *mashrabiya* as a projected lattice screen serving the purpose of maintaining privacy without hindering airflow. It can be concluded from the definitions above that *mashrabiya* are an important architectural element which provide natural light, identity, privacy, beauty, and air regulation.

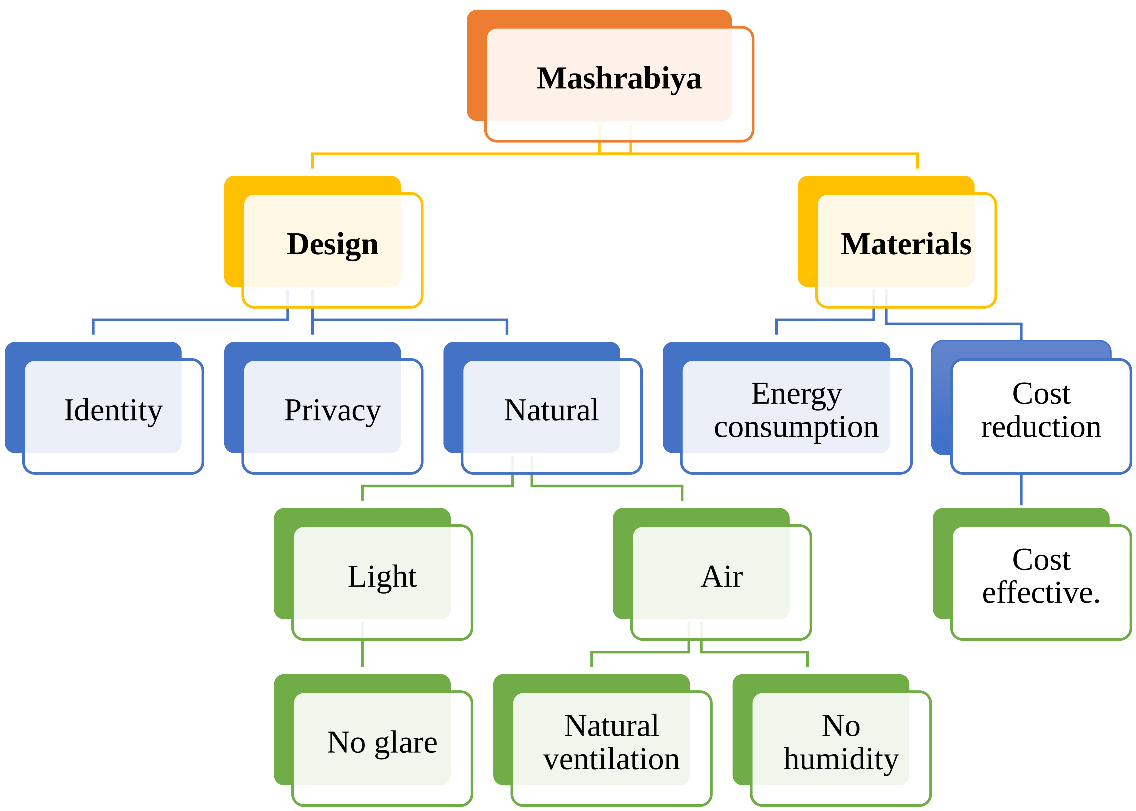


figure 2- 21 Mashrabiya design and function (Source: Alghamdi 2017)

Table 2- 6 Mashrabiya definition

Author	title of research	Definition
Battarjee (2010)	Performance of shading device inspired by traditional Hijazi houses in Jeddah Saudi Arabia	The wooden lattice work structure that is projected off a wide opening in facades of houses. A lattice window structure or screen.
Akšamijaet al. (2013)	Experimental study on the effect of *mashrabiya* on natural ventilation	The wooden lattice work structure that is projected off a wide opening in facades of houses. A lattice window structure or screen.
Al Hariri's		A vent or whole in the wall.
ALjofi/ 2005	The potentiality of reflected sunlight through Rawshan screens	Architectural device made of a combination of wood strips and screens, which is commonly used, for large external openings.
Saini/ 1991	Building in hot dry climates	A projected bay window with decorative wooden screens as an enclosure
Mortada 2003/2016	Traditional Islamic Principles of Built Environment	Bay window with wooden lattice screens to provide privacy without impeding the flow of air.
Kenzari and Elshestawy (2003)	The Ambiguous Veil on Transparency, the *mashrabiy'ya*, and Architecture	An architectural oriental wood lattice screen or veil
Al-murahhem (2008)	Behind a Roshan: visualising the Roshan as an architectural element in traditional domestic interiors.	A wooden projected window, which consists of horizontal and vertical wooden slats
Sidawi (2012)		An effective screen element for hot-arid climates
Ajaj (2014)	Re-Thinking Traditional Arab Architecture: A Traditional Approach to Contemporary Living	A shading device that has five functions: controlling the passage of light controlling air flow reducing the temperature of the air current increasing the humidity of the air current ensuring privacy

Having viewed various *mashrabiya* definitions from a number of authors it can therefore be concluded that not only are the functions pivotal in its energy performance, the design and materials complete its richness as a traditional architectural element fulfilling social, cultural and environmental needs such as privacy and architectural identity, as well as the significant role of reducing energy consumption in buildings.

2.5.2 Where in the World can *Mashrabiya* be Found?

Due to its multi functions, *mashrabiya* gained its popularity by spreading across the Islamic world, resulting in the adaptation of the design by various countries as well as changes in its name; for example, it is referred to as *roshan* or *roche* by the Persians which is further defined as the window or balcony. (Almurahhem, 2008) Clarifies that *mashrabiya* or *roshan* are the most common terms, and indeed are used interchangeably, that refer to the same architectural structure. The Egyptians use the word *mashrabiya* figure (2-21) while *roshan* is the term commonly used in Saudi Arabia (Batterjee, 2010).

While (Al Hariri, 1991) states that *roshan* is an Arabic word derived from the word "*rashun*" which means a vent or hole in the wall, Roshan also has origins from an Indian word "*rushaandan*" which means the source of light or clerestory windows near the celling. This word is composed of two parts: "*rowshani*", which means light, and "*dan*", which is translated as 'giver'. If the two meanings of the word are combined as one new phrase, "light giver". Iraqis refer to *mashrabiya* as *shanashil figure (2-22)*, yet the most commonly used term in Yemen is *takhrima*. This shows that while *mashrabiya* retained its functions the designs and name changed as various countries adapted it as an effective architectural element.

Table 2- 7 The various names of mashrabiya around the world (Source: AL Othman 2016)

The name	The Countries
Mashrabiya	Peru, Sudan, Australia, Syria, Palestine, Lebanon, Egypt, Spain
Roshan/Roche	Arabian Gulf Countries, Iran
Shanshol	Iraq
Jali	Bhutan, India, Pakistan
Aggasi	Bahrain
Takhrima	Yemen
Mushabek	Iran
Barmaqli	Maghreb Countries
Cumba	Turkey

2.5.3 History of Mashrabiya

It is unclear when *mashrabiya* were first designed; however, the **Tulunid era** (868-905) experienced the widespread of its use leading to the **Ayyubid period** (1171-1250). The buildings in this era, particularly roofing, was mainly constructed using wood, hence *mashrabiya* gained momentum in terms of use as woodworkers took advantage of the left-over materials. While the use of mashrabiya continued to spread, the design also developed with time.

figure 2- 22 Mashrabiya in Alsuhami house in Egypt (Source: Google Maps 2019).

figure 2- 23 Shanshol in Basra, Iraq (Source: Mohsen,2014)

During the **Abbasid period** (750-1258), *mashrabiya* became more common and the designs became even more complex and stylish, portraying the skill of the craftsmen. By the **Mamluk period** (1250-1517), the *mashrabiya* design extended to incorporate religious needs, promoting privacy by designing the geometric shapes which allowed women to see through the holes without being seen by the outsiders (Maspero, 1914). Due to its design, which addressed core Islamic values such as the environmental, social, and cultural, *mashrabiya* gained even more popularity until the **Ottoman era** (1517-c1805). Saudi

Arabiya adopted the use of *mashrabiya* due to its effective response to climatic and social needs. (Alshareef, 1996) defined *mashrabiya* as an Islamic architecture which has been modified and adapted throughout the centuries by various users. An example of the type of *mashrabiya* which has different upper and lower designs can still be seen on Bayt Al Suhaymi house in Cairo, Egypt. The house was built in the Ottoman period in 1648-1057-58 but was renovated in 1796-1210-11.

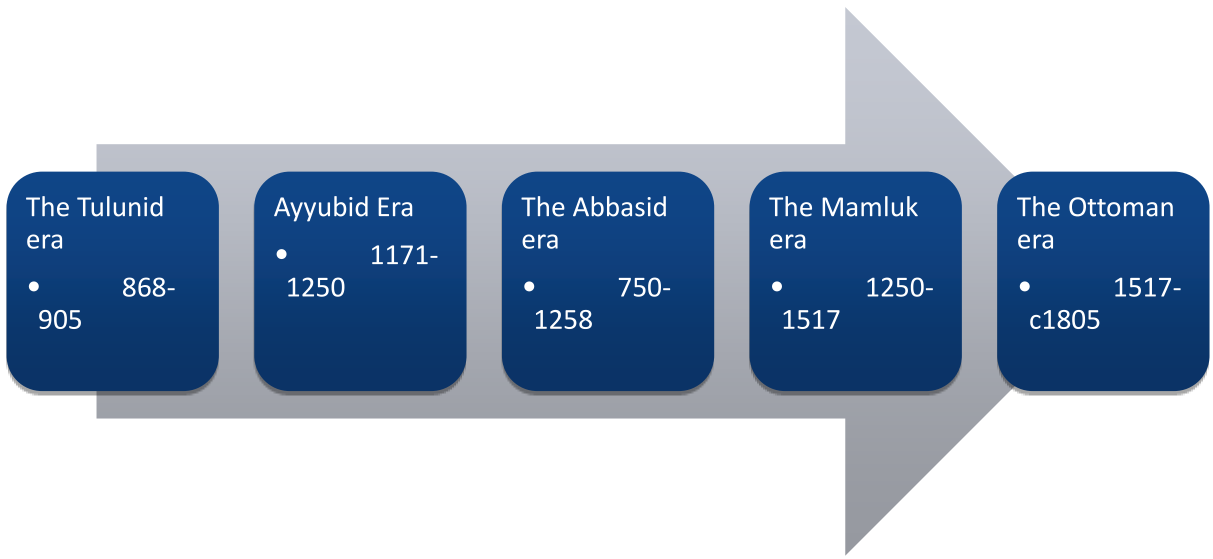


figure 2- 24 History of mashrabiya across different eras (Source: Alghamdi 2018)

2.5.4 Mashrabiya Functions

The definitions of *mashrabiya* clearly justify its acceptance and expansion. Its multiple functions promoted the quality of indoor environmental quality for the user's figure (2-25). To sum up the importance and role of *mashrabiya*, (Samakia, 2014) highlights the fact that in the past this architectural element served not only as a window and curtain but was also used as an air conditioner and a refrigerator. (Abdel-Gawad, 2012) goes on to say that *mashrabiya* have four traditional functions including control of sunlight, regulating air movement, ensuring privacy, and allowing residents a view of the outside world while remaining invisible to a passer-by. (Fathy, 1996) a well-known contemporary architect, outlined in his book five functions for the *mashrabiya*.

1. Controlling the passage of light
2. Controlling air flow
3. Reducing the temperature of the air current
4. Increasing the humidity of the air current
5. Ensuring privacy

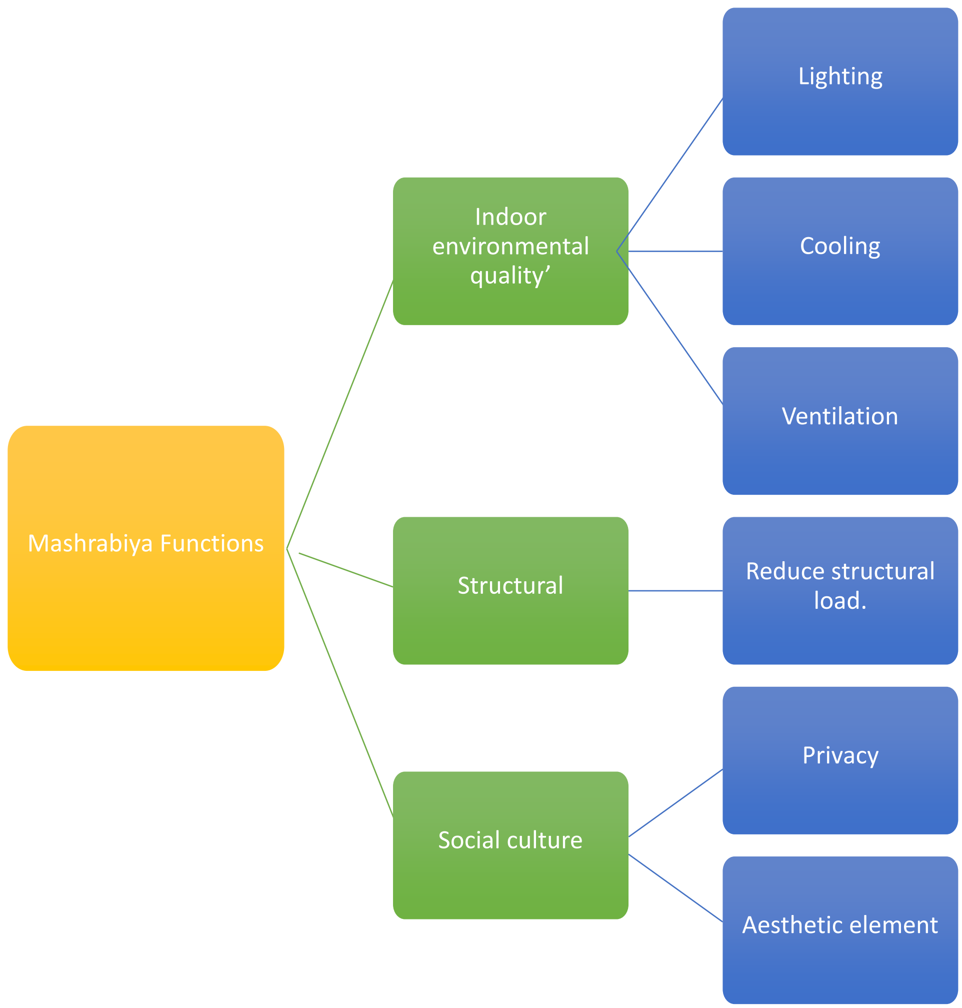


figure 2- 25 Mashrabiya function (Source: Alghamdi 2018)

figure 2- 26 Mashrabiya in Alsuhami house Egypt (Source: https://www.dreamstime.com/photos-images/mashrabiya.html)

Because of the determination to move towards sustainable architecture, as driven by the awareness of how natural lighting can impact energy consumption, architects are now adopting the use of natural light in buildings. (Sloan et al., 2013) are of the opinion that using the natural light from the surrounding sky and not just daylight can reduce electricity bills. They further state that buildings that are designed to maximise the use of natural lighting have the potential to reduce their energy consumption by 40 to 60% compared to conventional buildings. (Greely et al., 1990) state that there are many advantages to using daylight which not only include saving electricity and having a better view but also an exaggerated view of a bigger space.

According to the definition given by (Ajaj, 2014), there is an indication that *mashrabiya* provide natural air and light, enhancing indoor environmental quality. With extremely high temperatures in Saudi Arabiya, it is highly likely that direct sunlight may be an issue, particularly in summer, so *mashrabiya* can function as a filter for direct sunlight, reducing glare in a home. (Sloan et al., 2013) note that cooling and heating can be reduced considerably while creating a comfortable indoor atmosphere. As a solution to the issue of direct sunlight in summer, (Alshareef, 1986) states that the effectiveness of *mashrabiya* in reducing solar radiation is realised when part of the sunlight is blocked by the mashrabiya balusters, enabling some of the light to go through providing adequate lighting in the room. In addition, (Khan, 1986) reveals how *mashrabiya* screen geometries can provide a shade in the room as direct sun light is blocked by the frames surrounding the mashrabiya. (A-Allay, 1990; Sharma and Sharafat, 1986; Oliveira and Bittencourt, 1998) state that adjustments can be made to the design of the *mashrabiya*, particularly the louvers, ensuring they can be moved to regulate the amount of light so as to be appropriate for the comfort of the residents.

2.5.4.1 Natural Ventilation

Indoor physical comfort is vital for residents in terms of health by removing air pollutants and providing oxygen as well as for energy saving purposes. (Aksamija, 2015) defines natural ventilation as the means of saving energy ensuring indoor environmental quality for occupants. In addition, natural ventilation is defined by (Allard, 1998) as a process whereby air flows through an indoor space without using any mechanical systems. Ventilation is further subdivided into two types, cross ventilation, and single sided ventilation. *Mashrabiya* serve several functions. They allow for control of air flow and improve interior cooling. They also allow cool air to pass through the holes and dispose of hot air.

(Fathy, 1996) points out that the use of *mashrabiya* is not only focussed on its aesthetic purposes, but also the fact that it functions as a climate regulator tool. This is fulfilled by the size of the holes, which have a significant impact on indoor temperature, including the level of humidity and glare. The indoor cool temperature is achieved through the functions of the *mashrabiya* as air is regulated via their holes. Natural ventilation is beneficial in that it exchanges 'contaminated' air such as dust, gases, smoke, and body odours which may be irritants to the occupants. Individuals benefit from the evaporation caused by different temperatures causing a displacement that results in cold air settling at the bottom of the room while forcing warm air to rise, passing through the holes and leaving the room figure (2-27).

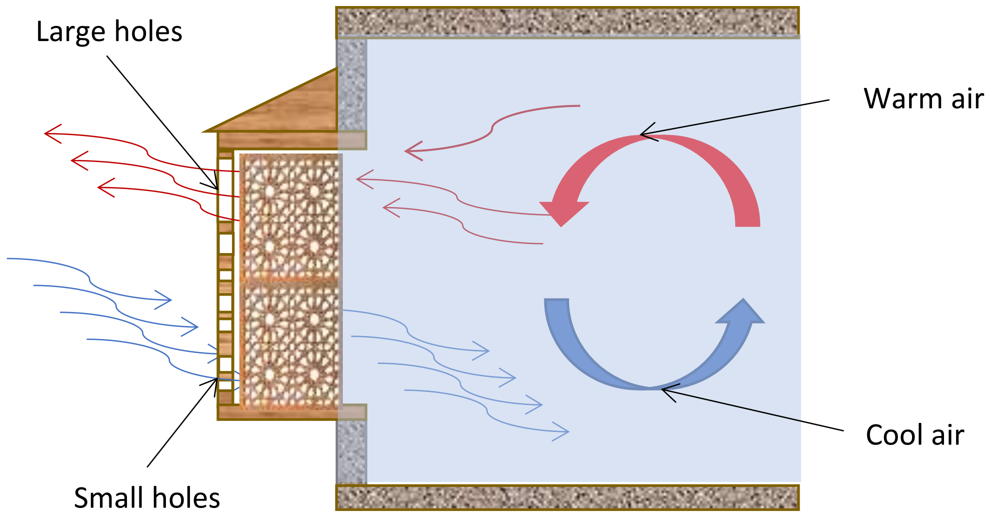


figure 2- 27 Cross ventilation through a single opening (Source: Alghamdi, S. 2019).

(Allard, 1998) highlights the fact that ventilation is important for providing both good indoor air quality and indoor environmental quality for occupants. Natural ventilation is cost effective as it uses the natural forces of wind which is pushed by pressure as well as the flexibility effect created by temperature differences in providing a quality indoor environment. (Allard, 1998) defines “human indoor environmental quality as conditions in which a person would prefer neither warmer nor cooler surroundings”. This indoor air quality is further defined as an environment or air which is free of pollutants that cause irritation, discomfort, or result in the ill health of the occupants.

2.5.4.2 Reducing the Temperature of the Air Current

Mashrabiya is an architectural element which has a perforated screen functions as a shading device and an air regulator to control air flow and reduce indoor temperatures. Through natural ventilation, a *mashrabiya* creates a draft which is pulled into the interior through its holes. The hot air in the house rises because of its density and escapes through the upper holes while the cold air from outside settles at the bottom, therefore making the indoor air cooler.

Mashrabiya also functions as a temperature regulator, while it allows the light through the holes; it also functions as a shading device which reduces the solar gain, hence lowering interior temperatures.

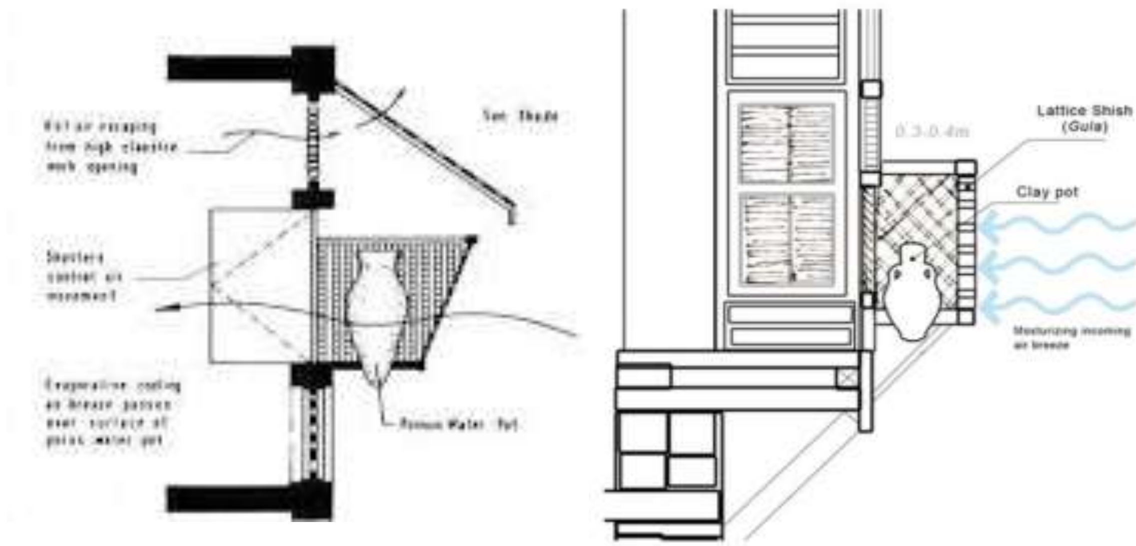


figure 2- 28 A porous clay water jar used to cool the air as it passes through the mashrabiya and into the building behind (Source: AL Othman, 2016)

2.5.4.3 Humidity

Humidity in buildings is said to be one of the contributory factors to sicknesses and diseases amongst the occupants hence the need to control it through natural ventilation. (Santamouris, 2006) further states that ventilation is essential in buildings to regulate indoor air quality while providing indoor environmental quality and controlling humidity. (Santamouris, 2009) further highlights the fact that appropriate levels of ventilation for humidity would control or prevent microbiological growth on walls, floors, and ceilings as well as protecting buildings from structural damage. (Fathy, 1996) points out that *mashrabiya* were highly considered for the fact that they functioned as a climate regulator tool. He further highlights the impact that the size of the holes has on indoor temperature, humidity and glare. (Fathy, 1996) further summarises the process of humidity in that as air is regulated through the holes of *mashrabiya* it is trapped by the wooden balusters, especially when they are cool. The sun then heats the wooden *mashrabiya* and humidity is released as air passes through the holes. If the sizes of the holes are larger, then the cooling and humidification rate is also increased. (Koenisberger et al., 1977) also state that humid air passes through the *mashrabiya* holes and moisture from the air is trapped in the wooden lattice, enabling dry air to enter the room. In addition, it can be said that the functions of *mashrabiya* superseded the environmental pressures by the provision of cool indoor environmental quality as well as dehumidifying homes. (Kamalski, 2015) further echoes the fact that as humid air passes through the lattice moist air is absorbed by the wood, which is also released when the sun heats the wood directly.

2.5.4.4 Privacy

Privacy using *mashrabiya* is achieved through its design, which comprises the upper level with tightly knitted holes situated at eye level. On the other hand, *mashrabiya* also has a lower level with a wider design. The design of the *mashrabiya* allows the residents to view the outside world while not exposing themselves to it. (Al-Allay, 1990) asserts that when looking through (*roshan)* mashrabiya from the outside world, the design blocks prevent one from seeing inside while those inside have a full view. (Feeney, 1974) further states that while *mashrabiya* fulfilled social and religious functions, as well as being suitable for Haramlek conditions, it also fulfilled the Mamluk and Ottoman regulations.

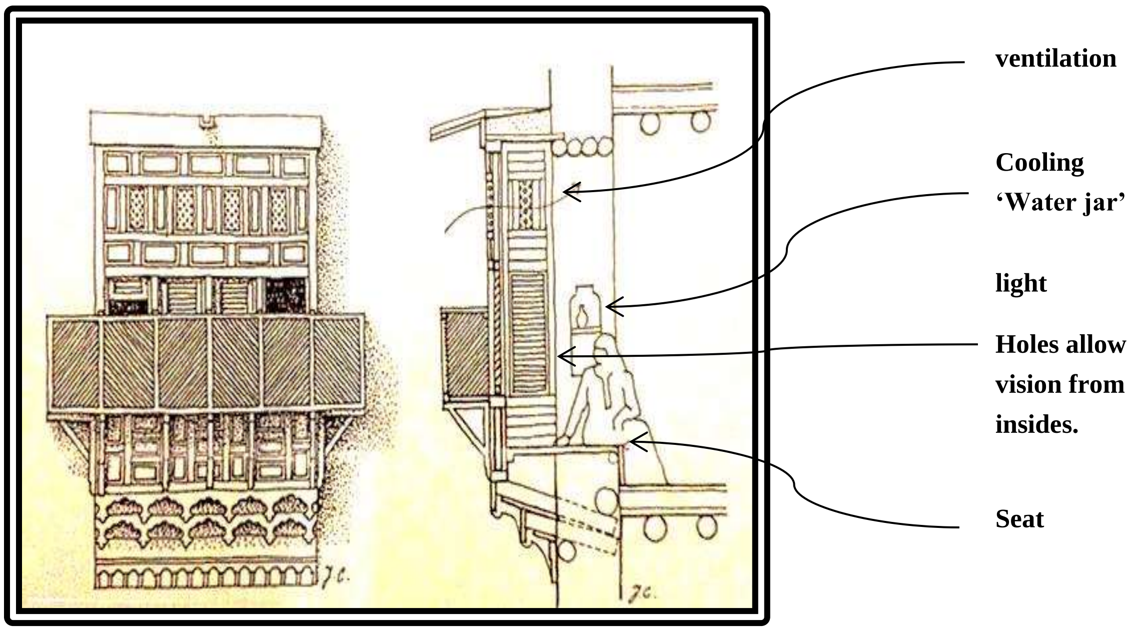


figure 2- 29 Various mashrabiya functions (Source: Ragette 2012)

The cultural and social function of *mashrabiya* was discussed in an article by Aramco. (Aksamija, 2015) further reiterates that *mashrabiya* were designed to allow for residents to sit on built-in benches enjoying the cool breeze and to watch people and street life. Nonetheless, it should be noted that *mashrabiya* maintain visual privacy for residents (Mortada, 2003). The main characteristics of Hejazi architecture embrace privacy as one of its major functions. Muslim women are expected as a rule and, indeed, obedience to Islamic law, to cover themselves. This adds to the value of privacy in a home to cater for the social needs of residents. Homes are designed to promote privacy hence the use of *mashrabiya* as architectural elements which extend to the value of privacy.

2.5.5 Material used for *Mashrabiya*.

Mashrabiya is an architectural element which is produced from wood imported from India used for roofing; scraps of wood were then used to design various types of *mashrabiya*. (Ben-Hamouche, 2013) states that *mashrabiya* were also named after *macherb*, a type of wood that the locals referred to as *macherbah*. Additionally, the Turkish, as stated by (Gocek, 2011) preferred to use the name 'Cumba' which means wooden lattice openings. This shows that while the name and the design varied from region to region, and indeed globally, the material used for *mashrabiya* remained the same.

2.5.6 Types and Design of *Mashrabiya*

Over the years the design of *mashrabiya* has progressed depending on the skills of the architects and the culture of the country. (Feeney, 1974) states that *mashrabiya* not only fulfil their aesthetic expectation by their geometric patterns or shapes, but they also fulfil both social and religious functions. This was adapted from the Quran the calligraphy design suitable for the Haramlek fulfilling Islamic regulations.

figure 2- 30 Mashrabiya Advantages (Source: Google Maps 2019).

(Aljofi, 1995 cited in Aljofi, 2005) noted that there are three main types of *mashrabiya*. These three types are the louvered walls and windows, screen panels and the cantilever. The types depended on the size of the lattice openings and style. (Mohamed, 2015) noted that the function of the cantilever was to increase the size of the upper levels. It also served as a shading element and protected residents. People walking by used the *mashrabiya* as protection against the hot sun and rain. As discussed, there are two types of *mashrabiya* (*roshan*). One type serves a shield or protection of one small opening in a room. The other type covers several openings and extends across the entire façade of the buildings from the floor up to the roof.

Fathy further explained that *mashrabiya* served as a climate control structural element. This is particularly important since *mashrabiya* are mainly found in hotter climates.
Other designs allowed for large pots of water to sit by the *mashrabiya* to remain cool. As noted in the article by Feeney, the *mashrabiya* “served, at one and the same time, as window, curtain, air conditioner and refrigerator.” (Feeney, 1974).

2.5.7 Abandonment of Mashrabiya

By the nineteenth century, during the Industrial Revolution, less people used *mashrabiya* in building their homes. Over time, the appropriate supplies became difficult and costly to acquire (Feeney, 1974) due to its way of production which included handcraft, this increased the number of skilled craftsmen began to decline. Furthermore, the introduction of air conditioning also led to a rapid decline in the use of *mashrabiya* (Akbar, 2012). Akbar further pointed out that as modernisation and globalisation began to spread and influence the Middle East, the use of *mashrabiya* became irrelevant (Mohamed, 2015).

Summary of results from previous studies

The information displayed on the table (2-8) is a summary of various aspects of building envelopes such as construction materials and thermal insulation types and position that have been researched over the years to find the impact these have on building energy performance to control the continuous increase of energy consumption in Saudi Arabia. The mystery over continuous increase has remained a subject of investigation in SA including the causes such as residents' behaviour, architecture, and climate. However, (Aldossary et al., 2013) researched on the houses and flats to find out how not only behaviour can be a contributory factor but also the design of the building. In the discussion of the design, (Aldossary et al., 2013) highlights the fact that (Taleb and Sharples, 2011) pointed out the need to make changes on the wall and roof insulation and external glazing. Having identified issues with design (Aldossary et al., 2013) recommends use of external shading device which this research aims at not only redesigning mashrabiya but also considering the needs of residents. Examples mentioned above and the table in table (2-8) clearly show previous research and the gap in the use of mashrabiya not only to reduce energy consumption but also provide privacy and identity.

With the building many attempts from various researchers to reduce energy consumption in Saudi Arabia (Alaidroos and Krarti, 2014) investigated the impact of energy performance on the building envelope including wall and roof insulation, windows area and glazing as well as window shading and thermal mass. According to the research, results showed a considerable energy reduction for both subsidised and nonsubsidised energy. The aim of this research is to extend from the outcomes above and aim to reduce energy consumption by adding mashrabiya optimising on its functions on indoor environmental quality. It is clear from the table that authors focused on different building envelopes.

In addition, (Aldawoud, 2012) focused on electrochromic glazing on exterior shading devices which function as blockers of the intensity from the direct sun hence reduce glare on which the results promote increased daylight in buildings. The findings showed that exterior glazing can enhance the reduction of solar gain as reflected by the investigations. Since this research has shown how the identity of the country has diminished all due to the introduction of the glass window offering residents an option for using window shading to provide privacy and therefore rendering results ineffective through the introduction of window treatment thereby limiting lighting, hence mashrabiya is hoped to be used in conjunction with double glazed windows and through its functions improve the indoor environmental quality while promoting privacy and identity

The further investigation regarding mashrabiya and indoor thermal environment and reduction of energy consumption where caried by (Maghrabi, 2000) using louvred windows to find out ventilation performance. According to the Maghrabi the changings in the louvred windows contributed to either poor or effective ventilation. Another investigation in mashrabiya included the lighting performance in residential buildings by (Al-Hashimi and Semidor, 2013) the results showed that mashrabiya with open Venetian blinds contributed to large patches of daylight. From the investigation above including those in table 2-8 it is clear that none of the researchers have investigated on the impact of mashrabiya on building energy performance and social culture aspect in hot climate. Although there are some researchers who investigated on *mashrabiya* and natural lighting and *mashrabiya* design with air regulator however, none have focused on the impact of *mashrabiya* on energy performance in residential buildings and social cultural aspects such as privacy and architectural identity in hot climate which is the gap.

This research is an extension of the previous investigations as it builds on already insulated villas to investigate the impact of *mashrabiya* on double glazed windows.

Table 2- 8 Summary of results from previous studies. (Source: Alghamdi, S. 2017)

Author(s)	**Title**	**Domains examined**	**Results**	**Sample**	**Data collection/**	**Country/ City**

					processing method	
(Saleh, 1990).	Impact of thermal insulation location on buildings in hot dry climates. Solar and wind technology	Wall thickness	Exterior insulation produced best energy performance but in air-conditioned space interior insulation is better.	Three different thickness of wall, 5, 7.5, 10 cm	Simulation	Riyadh
(Al-Sanea, Zedan and Al-Hussain, 2012)	Effect of thermal mass on performance of insulated building walls and the concept of energy savings potential applied energy	Wall thickness	Concluded savings of cooling load of 17% and 35%. Recommendation: placing insulation outside if continuous use of air conditioning.	6-30 cm thickness of heavy weight concrete	Simulation	Riyadh
(Al-Sanea and Zedan, 2011)	Improving thermal performance of building walls by optimising insulation layer distribution and thickness for same thermal mass applied energy	Thickness of walls	Comparison of three layer with one showed an increase in time lag from 6 - 11 h and a reduction of 20% in cooling load.	Three wall configuration walls with 1, 2 or 3 layers of insulation	Simulation	Riyadh
(Al-Sanea, 2002)	Thermal performance of building roof elements, Building and Environment.	Roof	Found that compared with an insulated roof with heavy weigh concert there was 32% reduction for polystyrene and 27% for extruded polystyrene.	Six typical roof structures used in buildings in the KSA	Simulation	Riyadh
(Abdelrahman, Said and Ahmad, 1993)	A comparison of energy consumption and cost effectiveness of four masonry materials in Saudi Arabia	Construction materials	Clay bricks consumed less energy by 16% compared to concert and 23% to sand line and 25% to prefabricated walls.	Four masonry materials clay, bricks, concert blocks and sand line bricks and prefabricated walls.	Simulation	KSA
(Aldawoud, 2013)	Conventional fixed shading	Window	The window shading and glazing	Four modes 1- double glazing	Simulation	Riyadh

	devices in comparison to an electrochromic glazing system in hoy dry climate. Energy building		properties have great impact on reducing solar gains in hot climate. Electrochromic glazing offered the best energy performance.	with no shading 2- double glazing with 1.5 cm overhang projection 3- double glazing window with overhang and side figures 1m projections 4- electrochromic glazing with no shading		
Abdelrahma and Ahmad (1991)	Cost-effective use of thermal insulation location on building in hot dry climates, solar and wind technology	Type thickness of wall	Clay bricks require less insulation. e.g., in hot and humid climate, the wall with concrete block need insulation of 5.5 cm, clay bricks require 5 cm.	Polyurethane board expanded polystyrene board for either clay bricks or hollow concrete block wall.		Dhahran
(Al-Sanea, Zedan and Al-Hussain, 2013)	Effect of masonry material and surface absorptivity on critical thermal mass in insulated building walls, applied energy	Effect of insulation on type of wall and location	Walls with solid concrete blocks achieve higher energy savings. Walls with inside thermal mass layers performed better than walls with thermal mass located outside.	Insulation mass varied between 0-50 cm. Investigations into effectiveness of thermal mass inside and outside.		Riyadh
(Aldossary, Rezgui and Kwan, 2014)	Domestic energy consumption pattern in a hot and arid climate a multiple case study analysis. Applied energy.	Roof, wall, and window	Energy consumption of the residential building is around 185.4 kWh/m^3. High energy is due to lack of thermal insulation for wall and roof. Poor performance of single glazing windows showed reductions of 15 and 34%.	Six selected homes, three typical detached houses and three typical apartments.	Simulation	Riyadh
(Aldossary, Rezgui and Kwan, 2014)	Domestic energy consumption	Roof, wall, and window	Energy consumption of the residential building	Six selected homes, three typical detached	Simulation	Jeddah

	pattern in a hot and humid climate a multiple case study analysis. Applied energy.		is around 185.4 kWh/m^3. High energy is due to lack of thermal insulation for wall and roof. Poor performance of single glazing windows showed reduction of 21 and 37%.	houses and three typical apartments.		
(Al-Saadi and Budaiwi, 2007)	Performance-based envelope design for residential buildings in hot climates	Windows	When proper envelop design is used significant energy is reduced in hot climates	Four glazing	Simulation	Dhahran and Riyadh
(Aljofi, 2005)	The potentiality of reflected sunlight through Rawshan screens	The reflected sunlight through Rawshan	The results showed the high levels of light in the central zone with 10-23% and 10% less at the end for irregular shapes cells.	Six panels of different cell compositions.	Experiment	Dammam
(Alaidroos and Krarti, 2015)	Optimal design of residential building envelope systems in the Kingdom of Saudi Arabia	Building envelope	Subsidised cost case. Energy savings of 39.5%, 33.7%, 35%, 32.7% and 22.7% in Riyadh, Jeddah, Dhahran, Tabuk and Abha, respectively. Unsubsidised cost case Energy savings of 47.3%, 41.5%, 43.19%, 41.1% and 26% in Riyadh, Jeddah, Dhahran, Tabuk and Abha, respectively.	Five climatic zones.	Simulation	Riyadh, Jeddah, Dhahran, Tabuk and Abha
Aksamija (2015)	Experimental study on the effect of *mashrabiya* on natural ventilation: difference between normal	*Mashrabiya*	An experiment examined the effectiveness of various sized holes on *mashrabiya* in regulating air.	Used three different sizes and shapes of holes.	Experiment	Not stated

	windows and *mashrabiya*.					
Alghamdi, S. (2020)	The impact of *mashrabiya* on building energy performance and social cultural aspects in hot climate	*Mashrabiya*	Aims to examine energy consumptions and privacy by re-instating *mashrabiya* in contemporary residential buildings.	A typical villa in Albasateen resident.	Simulation field surveys, case studies, physical measurements	Jeddah

2.6 Conclusion

The framework of this literature review is divided into four parts which have include energy consumption, architectural elements which affect building energy performance studied by various researchers. In addition, the section, summarises social cultural aspects and history of mashrabiya and its functions. The above aspects will be elaborated in the light of the main objectives of this research. Energy consumption has been identified as an issue in Saudi Arabia, therefore, this study has derived methods of research to find viable solutions to the stated problem. The comprehensive review of literature has examined the increase in energy consumption from the global perspective, before focussing on the Middle East and GCC countries, then Saudi Arabia. This information on the history of energy consumption and the factors causing this will inform the research and conclusions drawn into the implementation of *mashrabiya*.

The main factors affecting the energy increase in Saudi Arabia are buildings, the population, and climatic conditions. While each of these factors have been subjected to a range of research, experts seem to agree that they have all played some role in increasing the level of energy consumption in modern Saudi architecture. The transition in building styles reveal a shift from traditional to contemporary styles, leading to a loss of privacy and architectural identity. The discussion shows how the population from neighbouring countries in Saudi Arabia led to growth in population, which also led to a high demand in buildings that resulted in individuals building to express their own cultures.

The definition of *mashrabiya* reveals its historical effectiveness as hidden in its functions, such as residents identifying their homes through this architectural element. *Mashrabiya* were used in the past not only for identity purposes but also to ensure greater privacy and air regulation for indoor comfort.

The chapter highlights the connection between orientation and energy consumption, specifying factors such as heating, cooling, and lighting. Rises and falls in temperatures and air speed can have a negative impact on indoor environmental quality. While *mashrabiya* is one architectural element which would be ideal as a solution to the continuous increase in energy consumption.

In summarising the climate, traditional buildings were constructed to suit the environment, using less energy. The research shows that not only were the buildings a cause but also the problem, which is inherent in shifting from traditional buildings to more contemporary styles, leading to inefficient design and the loss of both architectural identity and privacy.

The results, however, revealed further understanding of the factors that are contributing to the continuous rise in energy consumption in terms of the orientation of buildings and residents' behaviour, not merely the architectural elements or operational systems as structured by the interviewer.

In the social cultural aspect, privacy is highly valued in Saudi culture, however the adaptation of contemporary architecture revealed a negative impact on the architectural identify which led to the loss of privacy. In the last section *mashrabiya* which is pivotal in this research has been described first by giving various definitions from different authors, history, functions, and designs.

CHAPTER THREE

3.Study Context: Jeddah as a Case Study

3.1 Introduction

This chapter includes the extended justification of the basis of the research regarding the choice of the city of Jeddah by elaborating upon its historical background, which includes the location and the geographical region in which it lies. Within Jeddah is a historic ancient city called ALbalad which is characterised by traditional buildings. There are several factors that have contributed to the continuous increase in energy usage in Jeddah which include population, climatic conditions, and buildings.

The description of Hejazi architecture shows the differences between the contemporary architecture which highlights one of the most vital architectural elements, *mashrabiya*. This chapter highlights the main factors that impact on building energy performance in residential buildings in Jeddah and the significance of *mashrabiya* in Hejazi architect.

3.2 Why Jeddah?

There are several reasons for the selection of Jeddah as a case study for this research. One of these includes the importance of Jeddah city, its location, climate, and Hejazi architecture and mashrabiya as its most significant architectural element. Jeddah also has many traditional architectural buildings. This enables the researcher to highlight the major changes in Hejazi architecture and the causes for the change as a result of the increase in population, which led to the adoption of contemporary architecture. The increase in population led to a need for more homes which meant people built individual homes without complying with council regulations, thereby expressing their own cultures. This diversity in building contributed to an increase in energy consumption which became a major issue in the new buildings, and which has never previously been experienced in Saudi Arabia. The research is centralised mainly on villas which are built and owned by residents of which Jeddah is a city with Albasateen district fulfilling the characteristics above. This approach is expected to reveal the issue of privacy, identity, and continuous increase in energy consumption, particularly in these newly built and owned villas. It will further show loopholes within the council organisation, especially regarding the lack of enforcing the law as far as town planning is concerned to ensure building standards are adhered to in order to promote identity, privacy and conservation of energy in Jeddah. This is echoed by (Brebbia and Clark, 2014) who report that Jeddah experienced high levels of deterioration in buildings which comprised both informal transformation as immigrants-built houses expressing their own cultures together with a lack of conservation management leading to a significant loss of identity which is referred to as physical character. As a result of this, (Brebbia and Clark, 2014) go on to say that the Saudi Commission for Tourism and Antiques (STCA) and Jeddah Municipality (JM) have been working together to ensure Old Jeddah is registered as a world heritage site at UNESCO.

The research investigates the use of *mashrabiya* in contemporary buildings in an attempt to reduce the continuous increase of energy consumption in Saudi Arabia. As an architectural element, *mashrabiya* was chosen for its functions which have proven over the years to be effective for both social and cultural aspects in hot and humid climatic conditions in Jeddah. By describing the history of Jeddah city there will be a clear indication of how *mashrabiya* were used in the past and when the citizens abandoned their use, including the justification for this abandonment. It should be noted that while the climatic conditions in Jeddah remain more or less the same compared to previous years, the situation regarding energy consumption has changed significantly reflecting a continuous rise as the years have progressed. This will show how *mashrabiya* performed under those climatic conditions and whether shifting from traditional to contemporary style and eliminating *mashrabiya* could have been one of the factors that contributed significantly to the issue of the growth in energy consumption and loss of identity.

Among the many reasons Jeddah was selected as a case study for this research is the location, which displays the richness of traditional architectural buildings and their response to the local climatic conditions. Jeddah grid location is 21°19’N and 39°12’E with an elevation of 3 to 15 m above sea level. The population of Jeddah is diverse and continues to increase, as highlighted by (Bagader cited in Brebbia and Clark, 2014, p. 365) which includes both national citizens and foreigners. According to (UNESCO 2014), the ethnic diversity encompasses 4 million people divided into approximately 53 % foreigners and 47 % citizens. Jeddah has expanded from a city which only occupied an area of only 100 hectares, as reported by (Bagader in Brebbia and Clark, 2014, p. 365) to a modern metropolis spreading as far as 32,500 hectares according to the city records in 2014. It continued to expand thereafter, as evidenced by the reports by (UNESCO 2014), reaching a current urban total area of 1,690 km^2. One major distinction about this historic city is that it is divided into its northern and southern regions essentially according to social status, where the less privileged occupy the south including ethnic groups such as the Al Handiwia, Al Rewais and Ban Malek which is the most common area for Indians, and Bengalis and Africans, although some disadvantage Saudis can also be found in these areas. As the city continues to expand, the privileged citizens and some Hejazi families who used to live in the historic old city have moved to the north (UNESCO, 2014).

3.3. Background of Jeddah

3.3.1 Location

Jeddah is the second largest city in Saudi Arabia, located on the coast of the Red Sea and the coastal plain called Tuhama in the west central part of Saudi Arabia figure (3-1). According to (Bagader cited in Brebbia and Clark, 2014, p. 365), Jeddah is a historical city which is not only referred to as Jeddah, Jiddah or Juddah but also as the Bride of the Red Sea. It is also known as the Port of Two Holy Cities as well as the gateway for pilgrims to the Islamic holy cities of Makkah, which is located 80 km to the east of Jeddah, as well as Madina. Its economy depends on trade, maritime related activities such as fishing, ship building as well as hospitality and tourism.

Figure 3- 1 Geographical location of Jeddah in Saudi Arabia. Left: Jeddah city. Right: Location of Jeddah city in Saudi Arabia. (Source: Google Maps, modified by Alghamdi 2019)

Jeddah is considered the largest seaport in Saudi Arabia, which recognises its diversity. Jeddah plays a major economic role in the Saudi economy and is renowned as the leading capital city of trade due to its harbour linking the American, European, and African continents. As the gateway to the holy cities, Makkah, and Madinah, has drawn an influx of pilgrims on transit to Makkah and Madinah figure (3-2), the city is ranked fifth worldwide with regard to the continuous increase in number of visitors. One of the reasons of the unceasing influx of tourists is its Islamic background and location in which once in a lifetime, according to affordability, a member of a household is expected to make a Hajj pilgrimage.

Figure 3- 2 Jeddah's location between the holy cities. (Source: Google Maps)

The administrative regions can be subdivided into five main regions figure (3-3). In the middle of Saudi Arabia lies the Najd which features the courtyard, small triangular openings located in the outer façade of buildings enhancing cross ventilation. The materials of construction include mud. while Al Sharqiyah is in the eastern part which is characterised with courtyard, towers, and wind catchers to control ventilation. Located to the north is Al-Shamal, whilst Hejazi can be found in the western part. In the southern part of the Red Sea is the southern region namely (Al-Janoob) comprising of a multi-storey building with the ground floor which functions as a storage. Included in the upper walls were the openings through the walls to enhance air regulation. The buildings are constructed from pieces of flat stones the western region which is identified as Hejazi region according to (Kamal, 2014) includes many cities however, Makkah, Madinah and Jeddah are the biggest. The buildings are characterised by courtyards in Madinah area and air well in Makkah However, mashrabiya is well known as the most significant architectural element in Hejazi.

Figure 3- 3 Regions of Saudi Arabia. (Source: General Authority for Statistics 2010)

3.3.2 History and Development of Jeddah

Jeddah's architectural 'trademark' is its many houses that are about 100 years old. An example of these is the Nasif Historical house, which has seven storeys with more than 100 rooms in which King Abdul-Aziz AL Saud, the country's founder, used to live, as well as Jamjoum Historical House. This house has been turned into a museum. Due to its wealth in architecture and history, Jeddah has been redefined by (TECTURAE, 2012) as an outstanding heritage site, this information being included in the UNESCO world heritage site listing (2012).

- **<u>The period between 500 BC to the 9th century</u>**

From around 500 BC, Jeddah developed as a small fishing village when fishermen settled in the area after fishing trips around the sea. According to (Elshorbaji, 2010) the courtyards featured characteristics which fulfilled Islamic religious purposes which emphasised privacy and social needs. 605 AD saw Jeddah recognised as an official port for the Hajj pilgrims. The development of the port in the 7th century raised the status of the city under Rashidun when Caliph Uthman ibn Affan transformed it into a port. The fact that

Jeddah lies between Asia, Africa and Europe justifies the influence from the characteristics of the Hejazi architectural elements. Due to its geographical location between three continents, Jeddah was classified as the capital city of trade. The discovery of the ancient architectural structures in the period 974-94 CE reflected the influence of the Persians who controlled trade at the time between Yemen and Egypt. The transformations in Hejazi architecture progressed following the socio-economic changes within Jeddah through the traders. By the 10th century, the Persians are said to have occupied Jeddah but were subsequently expelled by the Makkah king.

- **<u>Mamluki Empire Era</u>**

The transformations in Hejazi architecture continued to progress as the economy developed. In the 13th century, during the Mamluki Empire (1248-1516) the designs of homes gained popularity as Spanish pilgrims to Makkah referred to the Jeddah homes built of stones and clay as the "Khans". The types of buildings were made of coral stones and limestone as high as three storeys. The coral blocks and mud mortar building materials were sourced from the local area in Manqabi Bay, an area in the northern part of Jeddah. It is this period that (Mohamed, 2015) indicates that *mashrabiya* are thought to have been used, most particularly in Egypt.

- **<u>Ottoman Period</u>**

The development of the economy and society led to the refurbishment of architecture during the Ottoman period (1517-1905). The 16th century, under Ottoman conquest, saw Jeddah's architecture being modernised into stone buildings, mainly to protect the city against Portuguese invaders. According to (King, 1988) the 17th century experienced a further development of the "Khans" from stone and clay and purposefully structured reeds to release heat at night, to three-storey stone buildings. (AlSharif, 1996) states that the majority of Jeddah's homes in the Hejazi region have multiple floors. The reason behind multi-storied homes was due to the levels of privacy required by Islam.

Traditional Hejazi homes were divided into private and semi-private areas; for example, the ground floor was an open area where male visitors were allowed, but the upper floors were secluded areas with higher levels of privacy, mainly for females and children. Hejazi buildings fulfilled three major construction practices including tall structures for ventilation purposes, large openings covered by (*roshan) mashrabiya*, and plastered walls serving as waterproofing against rain and humidity (Kaizer, 1984). A traditional Jeddah home incorporated both these Hejazi architectures, though emphasising the importance of privacy and social values. Therefore, a typical Jeddah home, as summarised by (Maghrabi, 2000), consisted of multiple storeys – from three to six floors – with a front entrance used by males and a rear entrance for females. The role of *mashrabiya* was to allow for privacy was to enhance privacy while still allowing residents to see outside. The progression in architecture veered towards geometric advancement in the 18th century with much decoration including bow windows and the use of *mashrabiya* (Roshan) made from wood imported from east India and the Mediterranean through Egypt. (Feeney, 1974) highlights the decline in the use of *mashrabiya* in the 19th century, during the time of the industrial revolution. According to (Al-Ban, 2016) the 20th century saw the rebuilding of Jeddah where the walls were repaired and built to as high as about three to four meters. The wall was built with large stones which were hexagonal in shape. It is claimed that not long ago, until around 1947, Jeddah was still surrounded by these walls which had an area of approximately one hundred and fifty square kilometre and had a population of only 35,000 people. Jeddah is characterised by its old town, Al Balad, which is situated in the middle of the city and referred to as Old Jeddah.

- **Pre-Oil Discovery**

The pre-oil discovery period in the 1950s, as (Ani, 1994) points out, was characterised by much of the building design being influenced by Western culture featuring palm houses and courtyards. Even though the designs had a strong Western influence, identity and privacy was nevertheless maintained.

- **Early Post-Oil Discovery**

(Alenezy, 2007) highlights the fact that the early post-oil period in the 1950s early 1960s was characterised by geometric facades, sloping roofs, spacious balconies, and air-conditioned interiors. The building materials included cement plaster, stucco, and natural stone. (Sidawi, 2012) identifies rapid economic development of individuals in the lavish decorations after the oil boom. The use of the air conditioning in this era saw the minimal use of *mashrabiya*, which were replaced by windows.

- **Mid-Post-Oil Discovery**

The mid-post-oil era is characterised by Palladian-style villas as residents adapted to modern architecture, which was associated with status in the 1960s and 1970s. (Alenezy, 2007) states that the late-post-oil period in the 1970s and 1980s was dominated by the adoption of courtyard and lattice screen elements.

3.3.3 Ancient and Traditional Al Balad (Old Jeddah)

Jeddah has one of the oldest towns in the country, Al Balad, which is rich in architectural history located in the heart of Jeddah figure (3-4). Jeddah was previously known as Al Balad before its expansion. Al Balad can be identified within the boundaries with apices at North: 21^{0}29’21” N-39^{0}11’26” E, South: 21^{0}28’48” N-39^{0}10’55” E, East: 21^{0} 29’07” N-39^{0}11’36” E and West: 21^{0}29’16” N-39^{0}10’52” E.

Figure 3- 4 ALbalad location in Jeddah (source https://www.researchgate.net/figure/Historic-Jeddah-AlBalad-27_fig1_325864736)

Al Balad has also attracted preservation and development funding to the value of about SAR 3.5 billion ($935 million), as approved by King Abdulla. As a result of the preservation project of Al Balad, Saudi Commissioner Tourism and Antiques (SCTA) has engaged in a joint study with the municipality on how to preserve Al Balad's buildings from disasters like flood and fire. In addition to this, the urban area between the old town in the east and western part, about 64.6 million square feet, was designated by Jeddah municipality as the development zone, the Special Development Zone (SDZ), that was approved by the king.

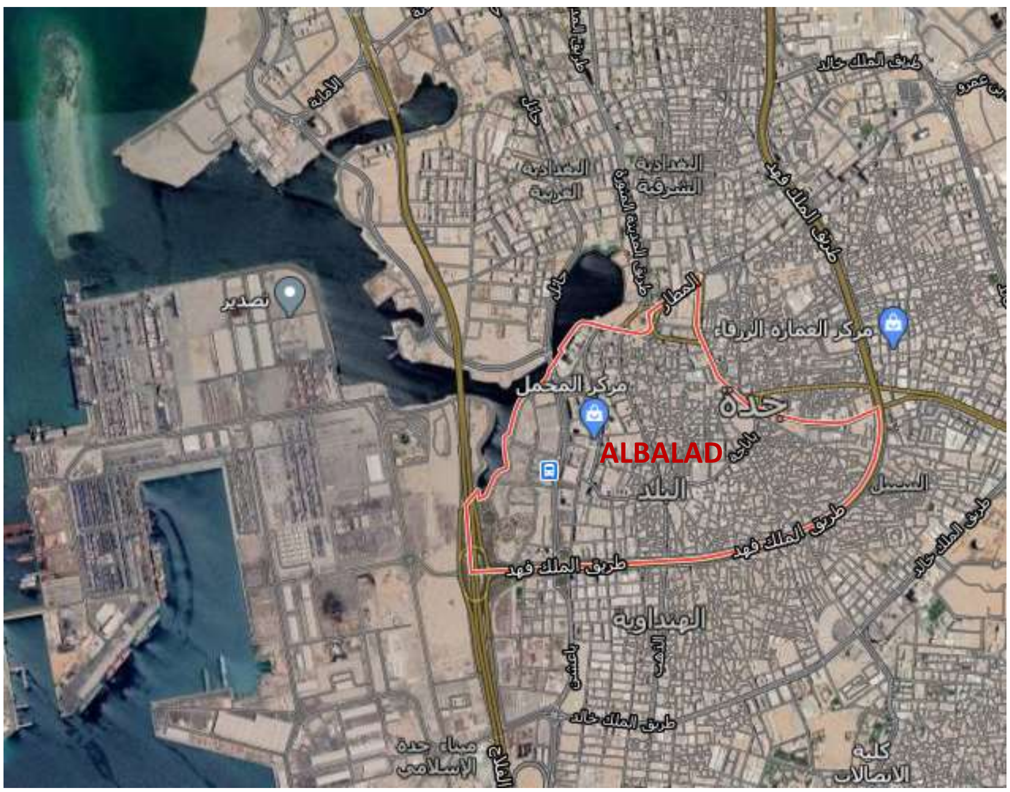


Figure 3- 5 ALbalad (Old Jeddah) (Source: Google map2019)

Figure 3- 6 Traditional building ALbalad (Old Jeddah) (Source: Google map2019)

- **Jeddah development**

Jeddah experienced major transformations in a period of 50 years beginning 1947 until 1998 where the area expanded from 1.5 km^2 by 500 km^2 in response to the housing needs and other services as stated by (Abu-Ghazzeh, 1998, p. 229). Figure (3-7) shows the period between 1964 to 2007 where Jeddah expanded from a small number of people which increased over time. Another major change included land usage on services such as residential areas, commercial, industrial, and public areas as well as informal settlement. The final development within the city was the transport infrastructure involving the highways, main roads, and secondary roads.

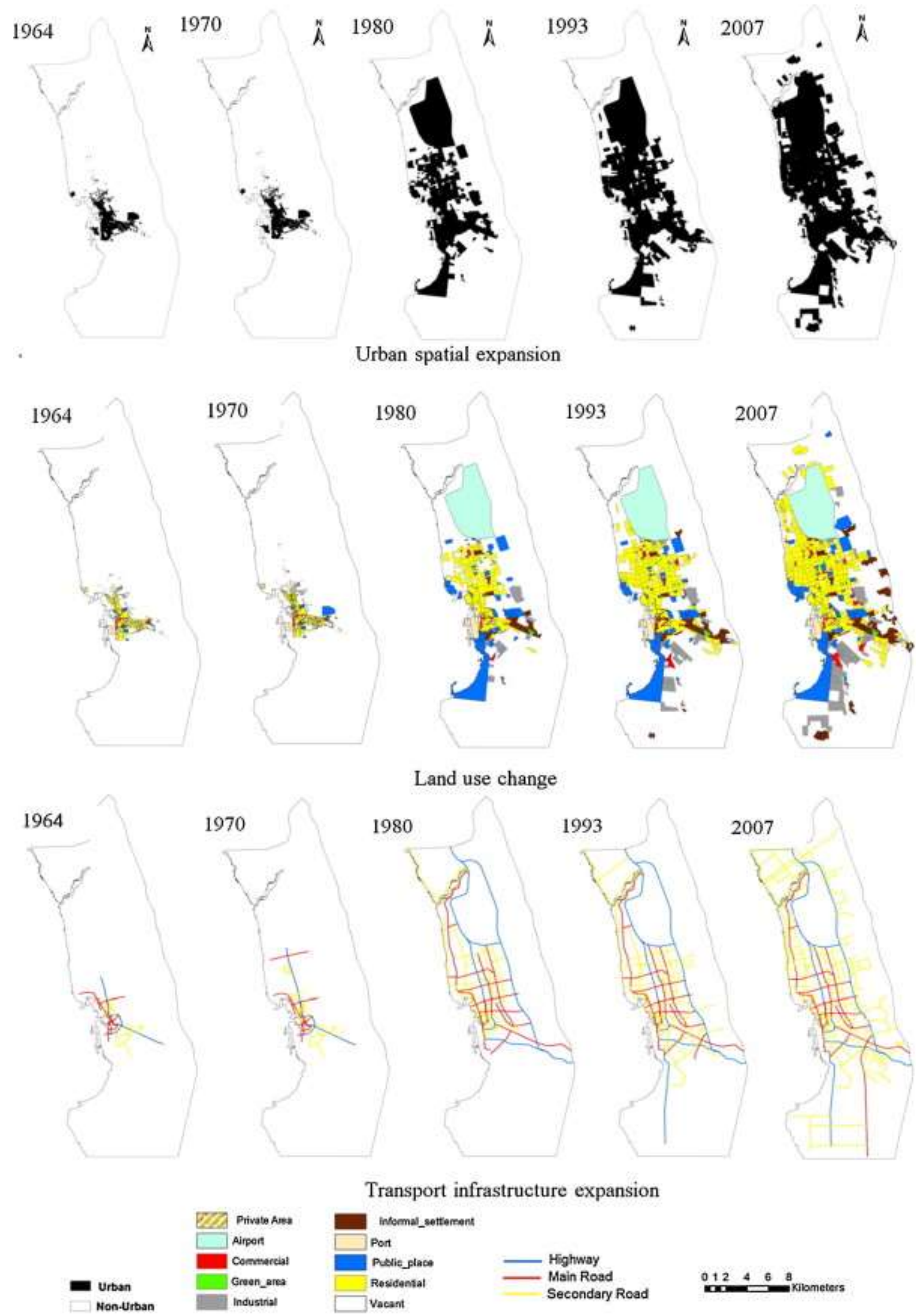


Figure 3- 7 Jeddah' spatial–temporal changes (Source: Aljoufie et al 2012)

Figure 3- 8 Mashrabiya in ALbalad, Jeddah (Source: https://www.shutterstock.com/search/old+jeddah,image_type=photo)

According to (worldatlas.com 2013), Jeddah has now developed to the extent that it is now known as the capital of business and tourism. To preserve its history, Jeddah has seen various projects, policies that contribute to the preservation or development of the city. Jeddah signed a memorandum with an association of companies, the City Centre Development Company (CCDC), which set plans to restore and build hundreds of buildings including Al Balad. In 1990, the Jeddah Historical Area Preservation Department was established to restore Al-Balad (HAPO) and about 40 buildings have since been renovated. While many areas in Jeddah have shifted to modern architecture, Al-Balad has preserved not only its architecture, but has also maintained the culture, food, and lifestyle. The structure of the home in Al-Balad reflects the trace of the privacy and identity which had previously been gradually wiped out by multiculturalism due to immigration and economic development. The houses in Al-Balad can be identified with wooden *mashrabiya* windows, also known as R*oshan*. Al-Balad is identified as a World Heritage Site as approved by UNESCO.

The map below figure (3-9) shows the location and the names of the districts in Jeddah including the population density per square metre.

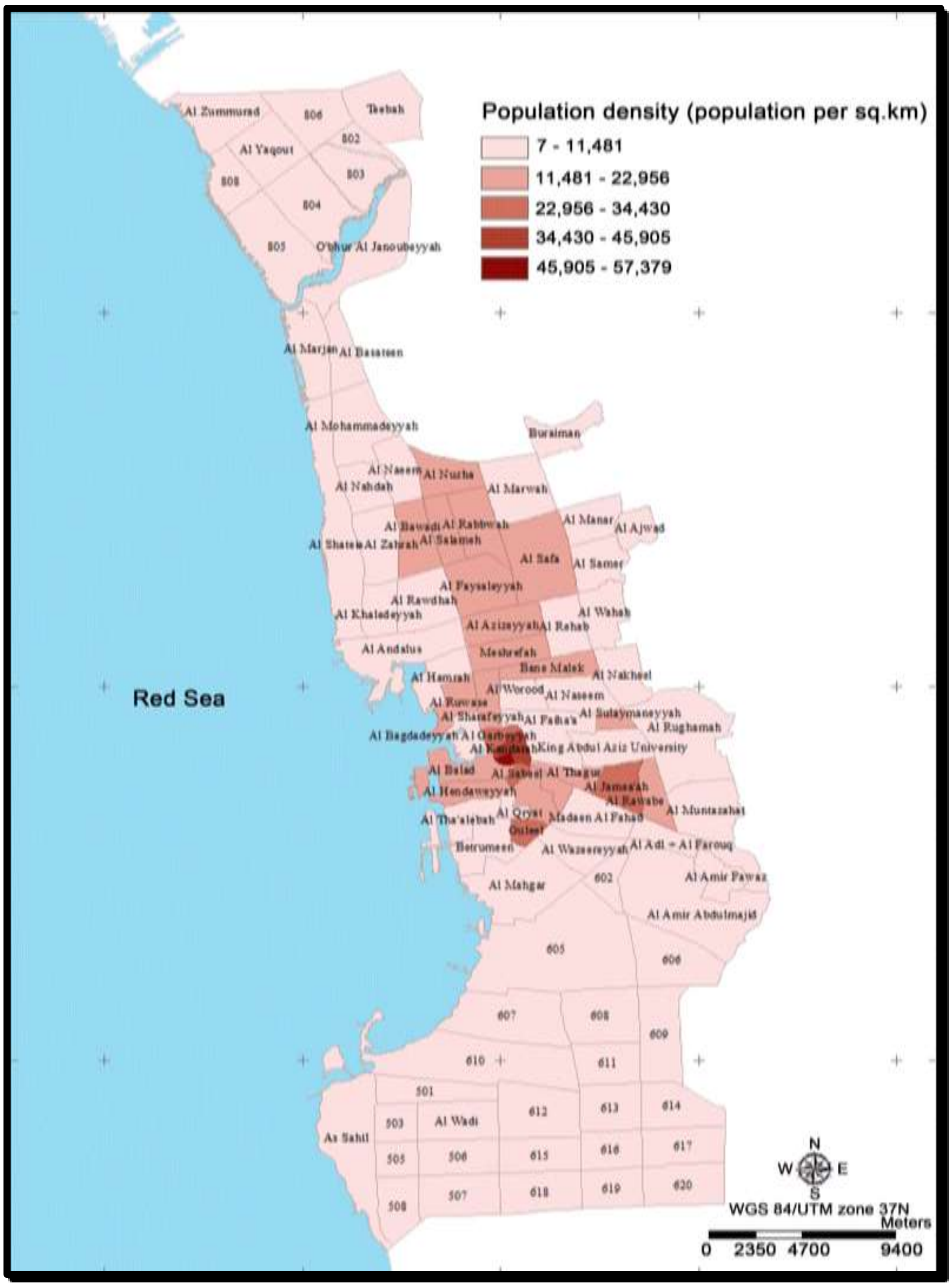


Figure 3- 9 Jeddah Districts (Source: Hamza 2016)

3.3.4 Traditional (Hejazi) and Contemporary Architecture in Jeddah

While traditional houses in Jeddah themselves differ in design, they share similar characteristics, for example, most homes are multi-storied with a minimum of three to six floors. It should be clarified that the higher the levels of floors, the more the privacy in the rooms. (Maghrabi, 2000) highlights the fact that middle floors are mainly for family. Buildings are characterised by two types of privacy, namely the vertical and horizontal. In order to fulfil the expected levels of privacy, the rooms which are specifically for hosting guests are situated on the ground floor, indicating 'semi-privacy'. However, the rooms, which are sub-divided into sleeping and living rooms, are more private and guests are restricted from entering these areas (Maghrabi, 2000, p. 35). *Mashrabiya* are (or at least were) viewed as one of the architectural elements that can provide privacy in Jeddah.

The rooms in Jeddah's homes are very big, mainly to promote ventilation from the sea breeze. In order to achieve this, most homes have a northern or northwest orientation. The houses in Jeddah had no courtyard in the past due to limited land availability. The remaining traditional homes in Jeddah had walls of 80 cm in thickness; however, these were reduced to 15 cm as the buildings increased in height. Traditional windows were not made of glass but of wooden *mashrabiya*. While the colour of the *Mashrabiya* represented status, differentiating between businesspeople, the middle class, and the poor through the use of light green, brown, and light brown, respectively. The special wood used for making *mashrabiya* and doors was imported from India; this type of wood could withstand humidity, salinity, and soil dampness. One of the downsides of Jeddah was its lack of water, resulting in residents building water cisterns under large houses. The Ottoman era has gained its popularity on the Jeddah houses named after the period due to privacy in homes. The structures of Jeddah's homes were hierarchical, where the lowest levels were mainly for servants with the next floor used for cooking while the third levels were for sleeping and the upper mostly for *majlis*. Even though Jeddah homes were tall, the design did not compromise on privacy.

Saudi Arabia experienced major developments due to the oil boom in the period between 1940 and 1970 (Abbu-Ghazzhe, 1998). The progress was not only in the economy but also in the housing industry whereas stated by (Al-Halthoul, 1981) the 1950's saw the introduction of villas with new construction techniques and materials including concrete. The contemporary architecture adopted new designs and styles, the results of most of these designs has been aesthetic, technical, and social failure. According to (Abbu-Ghazzhe, 1998) the residential buildings during this period were characterised by size which compared to traditional buildings is extremely large. The structure of the villa consists of two storeys and an annex with a maximum of 6 occupants and different internal spaces as well as the facades.

3.4 Factors that Affect Energy Performance, Architectural Identity and Residents' Privacy in Residential Buildings in Jeddah

It clear that the above-mentioned factors have a negative impact in residential building as the impact of one factor leads to the outcome which also influences the other since they are intricately connected. For example, growth in population in Jeddah led to the demand in more housing which led to the shift from traditional to contemporary architecture which is not climatic responsive. Due to harsh climatic conditions this led to the introduction of the use of air condition to improve indoor environmental quality thereby resulting in the increase in energy consumption.

3.4.1 Population

The factors are so connected that a change in one factor has an impact on the others; for example, the population in Jeddah, as a result of the increase in birth rate, and the movement of immigrants from various countries to Makkah and Medina for religious purposes but who ended up settling in Jeddah. The other reason the population has continued to soar in the city is the movement of people from the local villages to the city for economic reasons.

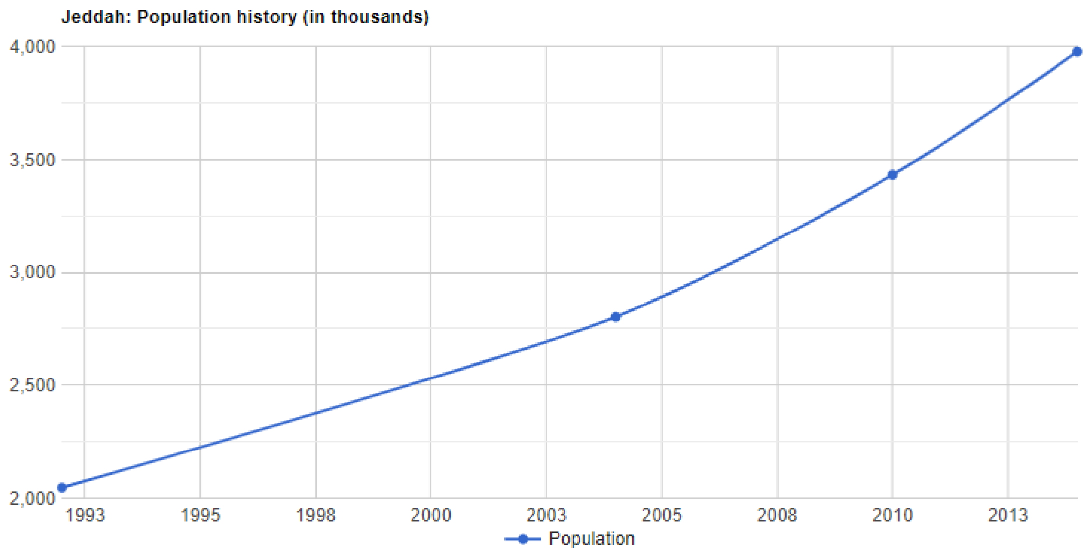


Figure 3- 10 Jeddah's population (Source: Jeddah Municipality (2002)

The increase in population resulted in the demand for more houses, which meant the government needed to construct more houses to accommodate the ever-growing population. It is the relaxation of the council building policies which saw the people from various background building houses expressing their individual cultures.

According to Saudi Housing Ministry in 2016 regarding the future housing project an announcement was made followed by an offer of 500 million square meters of land to developers for the construction of 1.5 million houses in a period of five years.

Jeddah is the second-largest city in Saudi Arabia. It is the gateway to the two holy cities, Makkah, and Medina, attracting many immigrants globally. Its central location in the western part of the Hejazi region encompasses both Makkah and Medina. (Ham et al., 2004, cited in Taleb, 2011) reveal that Jeddah is a diverse and rapidly growing city located on the shore of the Red Sea and the so-called gateway to Makkah and Medina. Jeddah is also known as the 'city of trade' due to its central location with links to America, Europe, and Africa. Jeddah’s economy is dependent on tourism and oil, attracting immigrants coming for both economic and religious reasons.

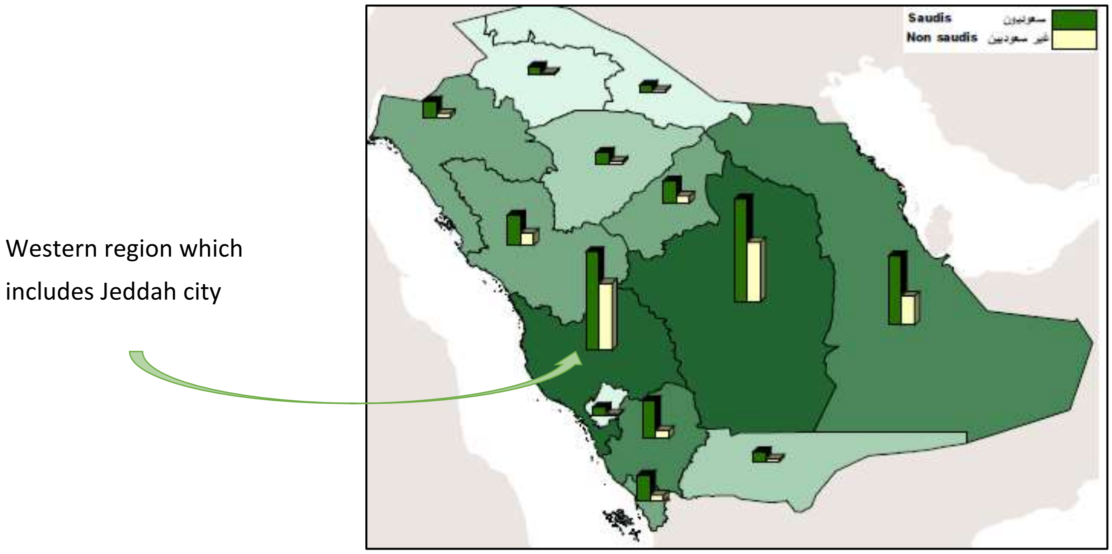


Figure 3- 11 population in Saudi Arabia (Saudi and non-Saudi) (Source: General Authority for Statistics 2010).

(Tarabulsy, 2008) states that Jeddah is viewed as the home for refugees, as evidenced by the visitors who travelled and later settled for religious purposes figure (3-11). These factors have resulted in an increase in population levels. In addition to the above, it should be noted that the population also increased because of internal movement from surrounding rural areas to the city, as well as the rise in birth rate. According to (Akbar, 2012, cited in Sidawi, 2012) the global demand for oil from Saudi Arabia led to economic wealth, which resulted in the population moving from rural areas to the cities. As the population grew, the city became more diverse and multicultural, resulting in the demand for more and varied houses. Several researchers have identified various factors, including population, which affect energy consumption. It is the view of (Al-Jamea, 2014) that the growth in population, which had reached 30 million by 2015, has resulted in demands for houses with almost 1.5 million new builds annually. However, it is clearly seen that the impact of population in Jeddah led to the demand for more houses. (Taleb, 2011) points out the need for residential buildings due to the rapid growth in population. To deal with the population problem, additional houses were built, but which gradually moved away from traditional to more contemporary designs. (Kamal, 2014) has drawn attention to the fact that Jeddah adopted western features and techniques to maintain indoor environmental quality within its buildings.

Hejaz region is in the west part of Saudi Arabia and consists of Makkah, Medina, Jeddah, and five more cities. Jeddah is positioned centrally to the continents of Europe, Africa, and Asia, allowing for easy trading access, for example, during the pre-Islamic era between Egypt and Yemen. While the port has been effectively used for trade purposes over the past 3000 years, it has since become useful for religious purposes as pilgrims visit the holy cities Makkah and Madinah. Some of the immigrants who visited Makkah returned to their respective countries while others settled, resulting in the continuous increase in Jeddah's population.

Figure 3- 12 Hejazi Region (Source: https://www.researchgate.net/figure/The-location-of-the-Hejaz-region-in-Saudi-Arabia)

Figure 3- 13 Traditional Islamic home. (source: https://www.pinterest.co.uk)

The lack of building restrictions in Jeddah Council led to the residents expressing multiculturalism through building style. This multiculturalism, which has had both negative and positive impacts to the identity and privacy in the city, as well as the architectural designs, was mirrored in the newly built homes as immigrants implemented their individual cultures. The increase in the number of immigrants also resulted in an increase in energy usage in the city.

3.4.2 Climatic Conditions

Even though Saudi Arabia is generally a hot country, there are, however, some areas that that experience different climatic conditions. This is reflected in the climatic zonal divisions such as hot dry maritime subzone, cold dry with a desert, and hot dry with a desert subzone, as well as hot dry with a maritime desert subzone, subtropical with a

Mediterranean subzone, and a mountainous subtype. Finally, the country also has an empty quarter (Alrashed and Asif, 2015)

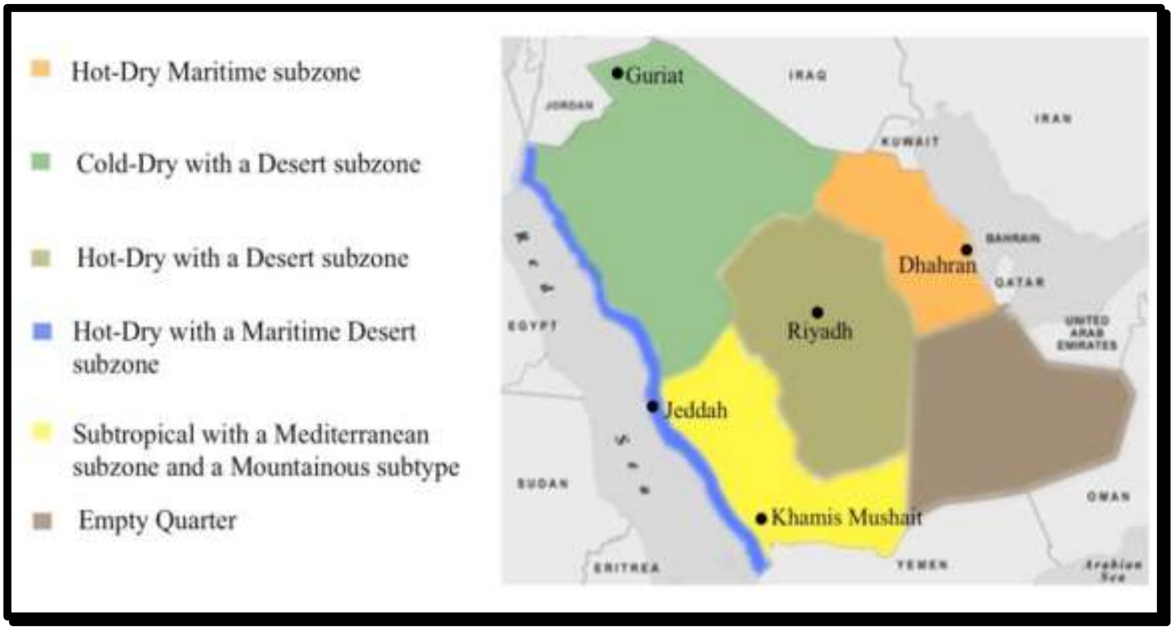


Figure 3- 14 Climatic zones in Saudi Arabia. (Source: ALRASHED, F and ASIF, M. 2015)

Regardless of the weather challenges, the Hejazi architecture showed the designs that cannot only withstand the harsh weather but utilised local materials as well as being cost effective. (Kamal, 2014) states that the Hejazi architecture was designed in response to the harsh climatic conditions as the buildings use cost-effective and locally produced materials. The weather can be a challenge to residents as they seek indoor environmental quality by using either heaters or air conditioners. As an illustration of this, residential buildings in Saudi Arabia use up to 52% energy (Alaidroos and Krarti, 2015), much of which is used for air conditioning (Al-Saadi and Budaiwi, 2007) as a result of the extreme local environmental factors.

The climatic conditions in Jeddah lead to a semi-tropical coastal climate with hot and humid summers while the winters are mild with relatively low humidity. This is as a result of the location of the city on the Red Sea. As stated by (Alitany, 2014), the fact that it is situated in the border between the Mediterranean and the monsoonal climate contribute to the present weather conditions. According to (Koenigsberger et al., 1977) the minimum and maximum temperature for both summer and winter ranges from 25 to 38^oC and 17 to 28^oC respectively. As a result of lying on the shore of the Red Sea, the relative humidity in Jeddah range between 56% to 67%.

Climate data for Jeddah (1985-2010) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	35.0 (95)	36.0 (96.8)	40.2 (104.4)	44.5 (112.1)	48.2 (118.8)	52.0 (125.6)	47.0 (116.6)	46.0 (114.8)	48.0 (118.4)	46.4 (115.5)	40.0 (104)	37.0 (98.6)	52.0 (125.6)
Average high °C (°F)	29.0 (84.2)	29.5 (85.1)	31.8 (89.2)	34.9 (94.8)	37.2 (99)	38.3 (100.9)	39.4 (102.9)	38.8 (101.8)	37.6 (99.7)	36.7 (98.1)	33.5 (92.3)	30.7 (87.3)	34.8 (94.6)
Daily mean °C (°F)	24.5 (76.1)	24.8 (76.6)	26.1 (79)	28.5 (83.3)	30.2 (86.4)	31.2 (88.2)	32.7 (90.9)	32.7 (90.9)	31.5 (88.7)	29.8 (85.6)	27.4 (81.3)	25.9 (78.6)	28.8 (83.8)
Average low °C (°F)	20.3 (68.5)	20.1 (68.2)	21.4 (70.5)	22.1 (71.8)	24.0 (75.2)	24.8 (76.6)	26.6 (79.9)	27.6 (81.7)	26.4 (79.5)	24.1 (75.4)	22.3 (72.1)	21.0 (69.8)	23.4 (74.1)
Record low °C (°F)	11.0 (51.8)	9.8 (49.6)	10.0 (50)	12.0 (53.6)	16.4 (61.5)	20.0 (68)	20.5 (68.9)	22.0 (71.6)	17.0 (62.6)	15.6 (60.1)	15.0 (59)	11.4 (52.5)	9.8 (49.6)
Average rainfall mm (inches)	9.9 (0.39)	3.7 (0.146)	2.9 (0.114)	2.8 (0.11)	0.2 (0.008)	0.0 (0)	0.3 (0.012)	0.5 (0.02)	0.1 (0.004)	1.1 (0.043)	26.4 (1.039)	13.1 (0.516)	61.0 (2.402)
Average relative humidity (%)	60	60	60	57	56	58	53	59	67	66	65	63	60

Figure 3- 15 Climate data for Jeddah http://www.city-data.com/forum/weather/2442773-rate-climate-jeddah-saudi-arabia.htm

The continuous increase in energy consumption in Saudi Arabia, particularly in Jeddah, is as a result of several factors, where the climatic conditions also contribute to this issue of energy consumption. The harsh weather conditions have driven residents to depend on air conditioning for indoor environmental quality.

- ***Sun paths***

The stereographic diagram is a representation of the sun paths in Jeddah. This diagram enables architects to make informed decisions as the suitable shading devices or mechanisms when designing buildings. According to (Masoud, 2014), stereographic diagrams show the daily movement and position of the sun in the sky throughout the year. The movement of the sun, altitude and climatic conditions determine the intensity of solar radiation that each location receives, which could be unfavourable to the building environment and more so the occupants. The city of Jeddah is located at latitude 21°32'N, 39°10'E 15 m (49 ft.).

Figure 3- 16 Sun path in Jeddah:(Source: Masoud 2014)

3.4.3 Architecture

In response to the location, particularly the climate, Muslim architects designed buildings which (Kamal, 2014) described as economical, not only using local resources but also being climate responsive and built with three principal reasons in mind, namely privacy, natural ventilation, and natural light. Traditional architecture can also be referred to as Islamic architecture based on its fundamental principles in the Islamic religion. (Rabbat, 2012) defines Islamic architecture as "… the architecture of these cultures, regions, or societies that have directly or via some intermediary processes accepted Islam as an integral component of their epistemological and sociological make up". Islamic architecture has progressed from the Prophet Mohammad Peace be Upon Him era, which was characterised by a simple lifestyle and modest living, followed by the Umayyad Dynasty in Damascus, Syria, which valued lavish palaces and attention to decoration. Another period was the Abbasid era who were more into developing ancient architect including mashrabiya. History shows that it is possible to reinstate *mashrabiya* from the Abbasid era. The fourth era was that of the Ottoman Empire, which valued privacy using *mashrabiya*. (Isteeaque, 1990, cited in Kamal, 2014) states that the Ottoman architectural style is 3-4 storey houses that benefitted from exposure to natural light and ventilation.

The traditional architecture of Jeddah has an Egyptian and levant influence (Mani, 1980). (Al-Lyaly, 1990) further elaborates those skills and techniques were brought in by immigrants (pilgrims) which became noticeable during the Ottoman era. Not only did the buildings gradually deviate from traditional Jeddah style (Hejazi architect), but materials also played a role as they were imported from other countries, including India (Bokhari, 1978). Among the imported materials was the Jawi wood which was used for *mashrabiya,* and this was specifically chosen for its resistance to humidity as well as being an insect repellent. Jawi (teak wood) is named after the country where it was imported from (Java). Not all materials were imported; mangaby and kasur are coral stones which were used for construction and were obtained locally, as reported by (Bhokari, 1978). In response to the location, particularly its climate, architects in Jeddah designed buildings that were economical, used local resources, and were climate responsive (Kamal, 2014). However, the lack of building restrictions implemented by the Jeddah Municipality Council led to the residents expressing their multiculturalism through their architectural styles. This multiculturalism has had a negative impact on the architectural identity of the city; it is evident in the homes built by immigrants expressing their individual cultures as echoed by (AL-Naim, 2008) that residents could not identify with the city of origin due to loss of identity. This led to increased numbers of immigrants, building less efficient houses resulting in increased energy usage in the city.

Figure 3- 17 Jeddah lost its architectural identity (Source: Google Maps 2019).

One of the major reasons for the loss of identity in Jeddah lies in the reluctance of the council to control infrastructure. As noted above, this has led to the residents building homes that reflect their individual cultures and preferences. In contrast to the idea of cultural influence, (Akbar, 2012) argues that the Western influence has played an important role in the changing identity of the city, as residents-built homes to suit their individual preferences, which gradually diminished the identity of the city as a whole. It has been claimed that many of these new buildings have no links to Hejazi architecture which follows Islamic values (Sidawi, 2012). (Akbar, 2012) condemns the ambition of residents to acquire a hierarchical status, claiming that this primarily occurs due to Western influence. This has led to recorded incidences of identity shock among citizens, due to the profound changes to their local environment (AL-Naim, 2008).

Figure 3- 18 Architectural identity (Source: Google Maps 2019).

It can be argued that the adoption of contemporary styles has a number of disadvantages over traditional local styles, such as the relative loss of residents' privacy. This can be explained in terms of the immigrants who settled in Jeddah having a different interpretation of the need for privacy than locals, even though they were of the same faith. Researchers also describe varied perspectives on the loss of privacy, with many arguing that Western architecture disregards privacy (Sidawi, 2012). However, scholars like (Akbar, 2012) argue that privacy is maintained in modern buildings. The cultural deference is viewed from the origins and cultural backgrounds of the authors.

As residents adapted the modern-style architecture, energy consumption in Jeddah began to soar figure (3-19). The poor design of some of Jeddah's more modern architecture has resulted in some houses having as much as 80% of their electricity needs devoted to air conditioning and refrigeration purposes (Akbari, Morsy and Al-Baharna, 1996). Studies have shown that traditional buildings consume far less energy than many contemporary structures (Kamal, 2014).

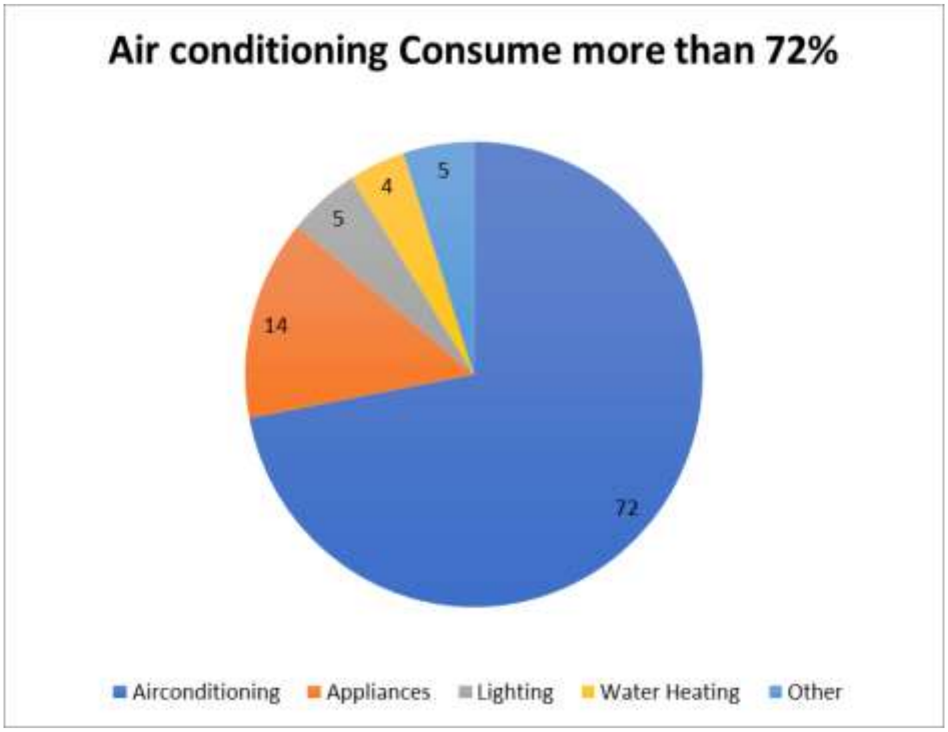


Figure 3- 19 Air conditioning consumption in residential buildings (Source: SEC. Annual Report)

Figure (3-20) below shows the amount of oil used in generating electricity from 2009 to 2014. According to the diagram, August was the highest in energy consumption with figures of about 0.9 million barrels per day while January and November are the lowest with close to 0.4 million barrels per day. the diagram shows the highest levels of consumption between the months of May and September whereas January to March and October to December show the levels of consumption, dropping slightly from 0.3 million barrels per day in January to March then gradually rising to as high as 0.9 million barrels per day and finally falling to as low as 0.5 million barrels per day in October to December.

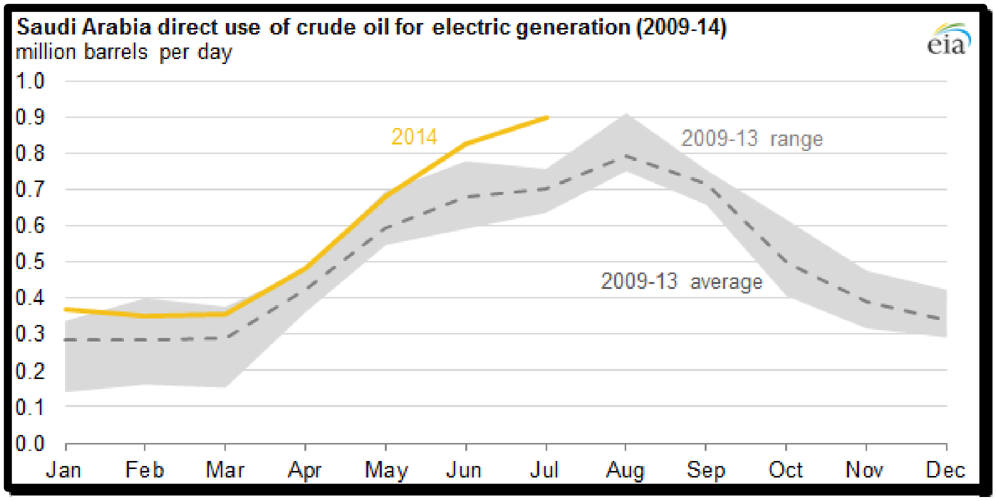


Figure 3- 20 Saudi Arabia typically experiences an increase in electricity consumption as domestic demand for air conditioning over the summer months. (Source: U.S. Energy Information Administration),

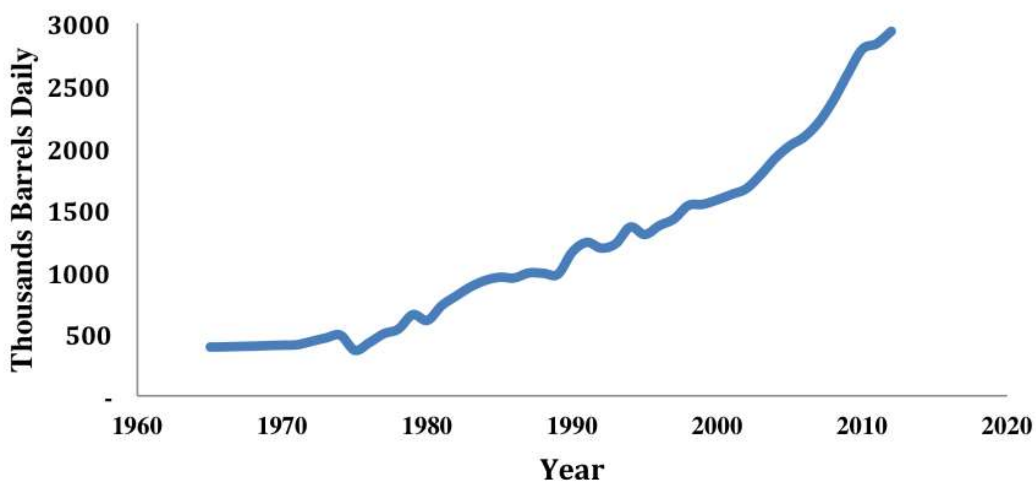


Figure 3- 21 Saudi Arabia Domestic Energy Consumption (source: http:// large.stanford.edu/ courses/ 2014/ ph240/ aljama1/images/f1big.png)

It has additionally been argued that the shift from traditional to Western styles has diluted the character and Hejazi architectural identity of Jeddah, with the adoption of contemporary styles contrasting with traditional design principles in many ways. The aspirations of individual citizens can also be viewed as potential reasons for the loss of architectural identity, as many residents copied Western designs to express their high social status. The gradual infusion of Western influence through the media is also highlighted as one of the causes of architectural identity loss. A related issue is that many modern buildings do not offer the level of privacy required by some religious views, perhaps due to the different standards or values held by immigrants settling in the city. This has led some to argue that Hejazi architecture has since lost its essence due to the influence of manmade philosophies. This has resulted in certain aspects of traditional buildings being modified or becoming less effective, providing justification for the widespread adoption of more modern styles.

The fundamental concepts in Islamic architecture which include Hejazi architecture are based on specific physical, environmental, social, physiological, and religious requirements (Sidawi, 2012).

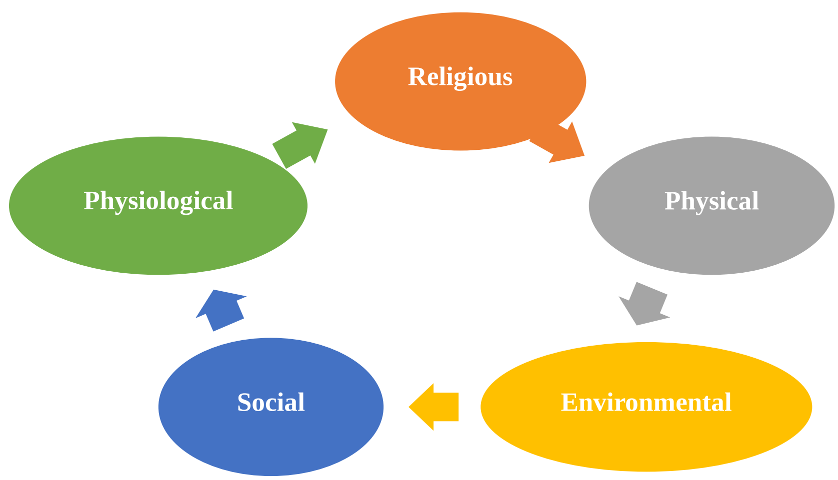


Figure 3- 22 The fundamental concepts in Islamic architecture. (Source: Sidawi, 2012) Chart by Alghamdi (2017)

It is clear from a historical perspective that there are a number of factors that have contributed to the decline of Hejazi architecture. One of the major causes is the economical aspect, which in this case is the discovery of oil that resulted in a wealthy society, and the parallel influence of Western culture. This became visible in the shift from multi-storey buildings to villas and apartments using concrete rather than locally produced materials, making these structures models of the early forties' era. According to (Akbar, 2012) subsidised electricity has been a major contributor to the move away from Hejazi architectural elements like *mashrabiya,* replacing them with the air conditioners that have contributed to the increase in energy consumption. (Sidawi, 2012) claims that the failure to identify traditional buildings may also be due to decisions on the part of architects to copy certain elements from Islamic buildings and to mix these with contemporary structures in an attempt to avoid a total loss of identity.

Despite the fact that various authors agree on the idea of Western influence, (Tarabulsy, 2008) expresses a controversial opinion by highlighting the multiculturalism of the city as a major cause of its loss of identity due to the fact that 'Jeddah is a home for refugees for centuries from diverse countries'. As these newcomers have integrated into the society, they have expressed individual identities in many ways, including in the designs of their houses. While the influx of immigrants and integration of new residents is viewed as a strength of the city, the architectural identity of Jeddah disappeared in multiculturalism. Having highlighted the architectural history of Jeddah and its development, it is clear from the activities within the country that there were many causes for the changes which have led Jeddah becoming a city with a lack of architectural identity, privacy and an increase in energy consumption that need to be addressed. One of these is the gradual move from traditional buildings to more contemporary styles, resulting in the abandonment of *mashrabiya* leading to a continuous increase in energy consumption. *Mashrabiya* with its multifunction not only provided social cultural aspect including privacy for the residents and architectural identity. Its functions also included the reduction the structural load. Due to its climatic responsive feature, *mashrabiya* provides natural lighting and ventilation as well as cooling the interior.

The views drawn from various researchers show the fact that architectural identity had been lost, although claims blamed Western influences on buildings, which meant adoption of contemporary styles that contrast with traditional designs in many ways. Internal aspirations are also viewed as potential reasons for this loss of identity as residents copied Western designs to imply their high social status. Gradual Western influence through the media is also highlighted as one of the causes of architectural identity loss. Another aspect of discussion is the extent of residents' privacy in which religious views are seen to have widened the gap as immigrants, despite being of the same faith, built houses with differing levels of privacy to the locals. While the loss of identity gradually unfolded, this also resulted in a loss of privacy. As the residents built their new homes, glass windows were introduced which brought a certain beauty and a new modernity, though leaving residents with reduced or little privacy. The realisation of the lack of privacy led residents to find ways of treating their windows to restore it; over the years, this has seen residents introducing shutters, trees, curtains, and other forms of protection to provide privacy in their homes.

Table 3-1 Factors that contribute to the increase in buildings energy performance

Factors that contribute to the increase in buildings energy performance

Growth in population	Increase in birth rate	More demand for houses	Shift from traditional to contemporary architecture
	Internal movement		
	Immigrants		
Climate condition	Hot humid		
Architecture (Buildings)	Construction elements	Windows	Orientation
			Shading
			Size
			glazing
		Thermal insulation	
		Roof	
		Walls	
	Operational system	AC	Quality and time of operation
		Lighting	
		Appliance	
	Orientation		

3.5 Impact of architectural changes on Identity, Privacy and Energy Consumption

One of the major reasons for the loss of identity lies in the reluctance of Jeddah Council to control local infrastructure. This led to the residents building homes reflecting their individual cultures. In contrast to the idea of cultural influence, (Akbar, 2012) argues that the Western influence played a role, especially due to the media, as residents-built homes to meet their individual preferences. The overall identity in Jeddah gradually diminished into contemporary designs which (Sidawi, 2012) claims have no links to Islamic values. In contrast to the above ideas, (Akbar, 2012) condemns residents' ambitions to acquire a hierarchical status which was mainly influenced by Westerners. The reflection of identity shock was noted by (AL-Naim, 2008), who states that citizens claimed to have awakened in a quite different environment to the norm.

It is clear that the movement towards contemporary styles had several disadvantages such as the loss of residents' privacy as the immigrants who settled in Jeddah, even though they were of the same faith, had levels of privacy that differed from that of their countries of origin. Researchers also show varied perspectives on the loss of privacy as (Al Ibrahim, 2003 and Omar, 2000, cited in Sidawi, 2012) are of the opinion that lack of privacy was because of the Western architecture which disregards it. In contrast to the loss of architectural identity, (Akbar, 2012) claims that privacy is maintained in modern buildings. This difference is explained by differences in authors' origins and cultural backgrounds.

3.6 Conclusion

Having discussed the history of Jeddah and its developments over the years, these changes contributed to issues the city is currently experiencing in relation to energy consumption, architectural identity, and privacy. Over the years, the population of Jeddah has increased not only because of its location but also the oil boom period which attracted people from all over the world and within the kingdom to settle there. It might also be noted that there have never been issues of energy usage, privacy, and architectural identity prior to the discovery of oil; the traditional buildings fulfilled the social cultural needs of residents, providing both privacy and architectural identity through the use of *mashrabiya*, which also functioned as an air regulator in cooling building interiors and shading residents from glare. The increase in population resulted in the demand to build new housing, with new settlers building their homes so as to reflect individual cultural backgrounds that were otherwise quite disparate in character to the Saudis; hence, privacy and identity issues began to creep in gradually. The chapter has revealed issues around building performance in a hot climate such as energy usage, social issues including privacy and identity using Jeddah as an example. these issues form a good basis for exploring options through integrating traditional approaches for example re-instating mashrabiya which has been identified as a significant architectural element in Hejazi architecture. The same *mashrabiya* which was abandoned as residents adopted the modern architecture is expected to be reinstated to restore architectural identity and privacy as well as reduce energy consumption not only in the city of Jeddah however, in all the other countries which have similar climatic condition.

CHAPTER FOUR

4. Research Methodology

4.1 Introduction

It is vital for the researcher to have a clear understanding on the suitable and effective research method as this may have major impact on the results. Pilot survey played a crucial role in the decision of the research methods used in this research as these were tried and proven to be effective. This also enabled the researcher to consider additional methods for validation purposes. Figure (4-1) below is an illustration of the theories, approaches and methods adopted in this research, including the application. To address the research question effectively, there are some views in which the discussion is hinged. This research is established on the positivists, constructivist, and pragmatists views. These views are also intertwined with mixed methods approaches hence the approaches were adapted for data collection include interviews, questionnaire, observations and taking of measurement and photos. While triangulation is a combination of methodological approaches it can also combine theoretical perspectives. The major reason for adopting triangulation is to negate or counterbalance the deficiencies of a single strategy in order to validate the results.

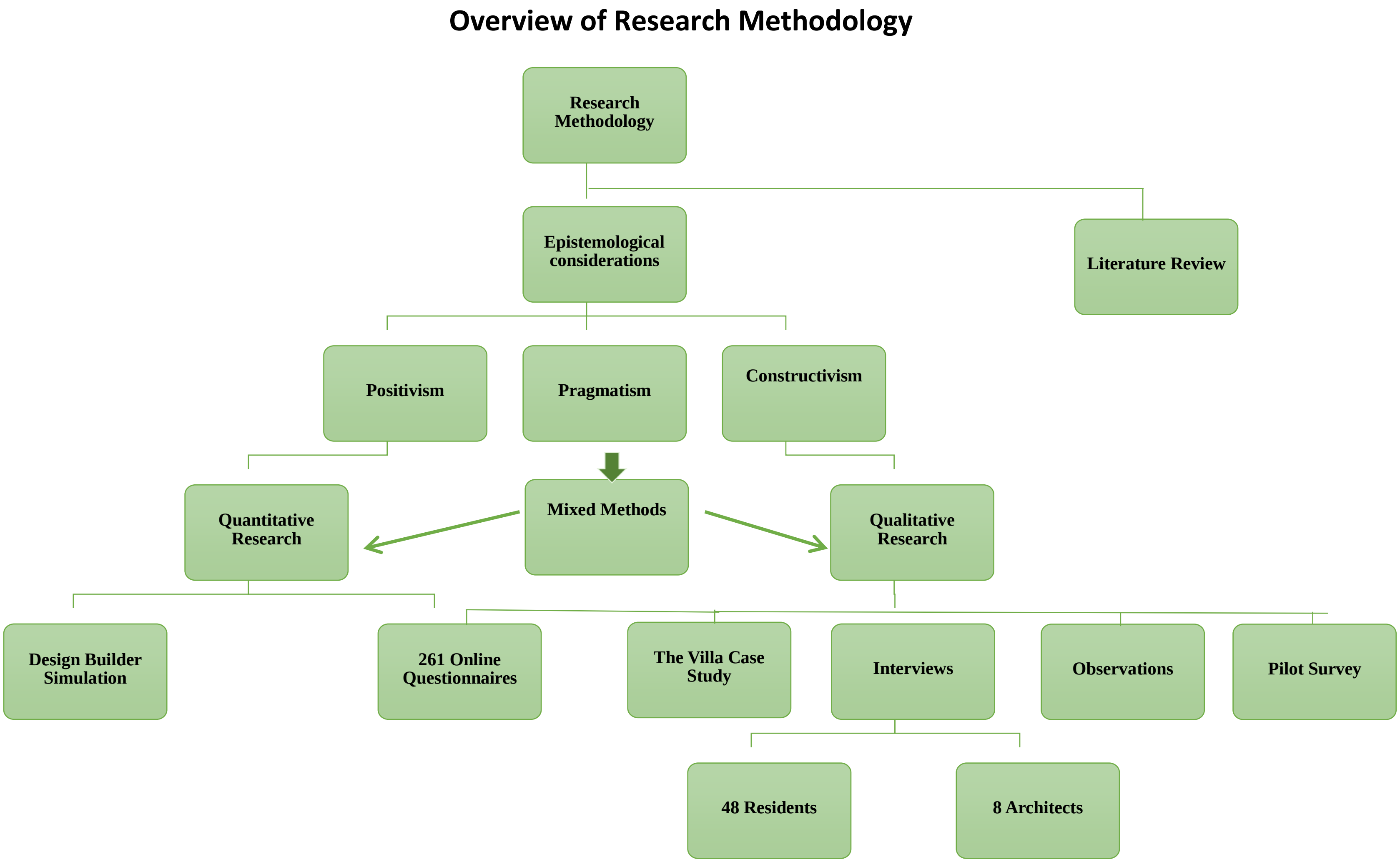


Figure 4- 1 Research methods (Alghamdi, S. 2017)

4.2 Research Philosophy

In epistemological considerations, there are four ways society views the world, for example, the postpositivist view, the constructivist, the transformative and the pragmatic perspective. While philosophical views are hidden in any research, (Slife and Williams 1995, cited in Creswell and Creswell, 2017) state that they have significant influence in the research hence there is a need to clearly show how they are incorporated. (Guba, 1990, p. 17, cited in Creswell and Creswell, 2017) defines these world views as a basic set of beliefs that guide action(s). These have been referred to as "paradigms" by (Lincoln, Lynham, and Guba, 2011), yet Crotty uses the terms epistemologies and ontologies, while (Neuman, 2009) refers to them as methodologies. These views generally show the perspective of the researcher and the how the research is carried out. Other key elements in the research include research approaches, research designs, and research methods. (Creswell and Creswell, 2017) assert that these are a representation of a perspective about the research. (Stanley and Wise, 1990, cited in Creswell and Creswell, 2017; Pronterotto 2005; Creswell, 2007) all believe that the interpretation and findings of the research stems from various approaches all influenced by epistemological views. Each researcher carries out an investigation based on how the truth is perceived. (Thyer, 2010) defines epistemological consideration as a focus on how the social world should be studied.

The knowledge of these perspectives will influence the conclusions that would be made regarding the research. It is clear that if the researcher believes that knowledge can be discovered through interaction with the environment, then certain research methods such as observations will be put first over others to collect data. This research opted for various perspectives to validate the results. Among these epistemological considerations, this research considered both the positivists, who follow the quantitative approach due to how data is collected based on how truth is interpreted, and the constructivists, who prefer an interaction with the environment using qualitative approaches in order to find meaning to the world and hence the use of observations and interviews. The interviews were carried out using a semi-structured questionnaire, in conjunction with which the researcher made a number of observations following with areas of observations table (4-1). The method of research is a combination of techniques and methods used for conducting research. Research method comprises the techniques for collecting data sample selection and the processing and interpretation of data.

4.3 Research Methods

Table (4-1) summarises the research methods used in the research including quantitative and qualitative approaches or mixed methods approach. The table shows various participants and their professional roles and status in the society. The qualitative approach shows examples of the research methods used in this research which are the interviews which was divisible into two parts the first part was government specialists and second part included 48 residents. In the quantitative approach two methods were chosen, the online questionnaire which attracted 261 respondents, taking indoor and outdoor measurements of air temperature, humidity, wend speed, natural and artificial lighting. The table also shows the aspects investigated using the methods of research highlighted above which include energy consumption, Hejazi architectural identity, resident's privacy and mashrabiya. The data collected from respondents enabled the researcher to select one villa from a total of 48 for further investigation using design builder. In addition, the data collected from questionnaires and interviewees contributed to meet the expectations of an improved mashrabiya. the next stage on the table shows the steps use in the simulation process while the last one shows the comparison of energy consumption results between existing villa with double glass windows and with added gypsum mashrabiya design 1and 2.

Table 4- 1 Research Methodology Summary (Source: Alghamdi, S. 2019)

<table>
<tr><th>Mixed Method Approach</th><th>Research Method</th><th>Participants</th><th colspan="4">Aspects Investigated</th><th>Results from research methods</th><th>Simulations steps</th><th>Evaluation</th></tr>
<tr><td rowspan="2">Qualitative and Quantitative approach</td><td><u>Interview</u> (Semi-structured Interview)</td><td>8 Specialists from 4 Government Organisation</td><td rowspan="5">Energy Consumption</td><td rowspan="5">Hejazi Architectural Identity</td><td rowspan="5">Mashrabiya</td><td rowspan="5">Resident’ Privacy</td><td rowspan="5">Choose one Villa case study from 48 interviewees.
Opinion from residents as guidelines for improved mashrabiya.
Design two simple Mashrabiya</td><td rowspan="5">1-Simulate the existing villa case study with and without AC.

2-Adding wooden Mashrabiya design 1to the existing villa and simulate with and without AC.

3- Adding wooden Mashrabiya design 2 and simulate the villa with and without AC.

4-Cchange the material to Gypsum

5-Simulate Gypsum Mashrabiya design 1-2 And with and without AC</td><td rowspan="5">Compare the energy consumption between existing villa and the villa with gypsum mashrabiya design 1-2.
How much energy is saved?</td></tr>
<tr><td><u>Observation</u> (Checklist table)</td><td rowspan="3">48 Residents Villa in Albasateen District</td></tr>
<tr><td>Quantitative approach</td><td><u>Measurements</u> (Indoor and Outdoor -Air Temperature -Humidity -Air Speed -Natural and Artificial Lighting)</td></tr>
<tr><td rowspan="2">Qualitative and Quantitative approach</td><td><u>Photo</u> (Indoor and Outdoor)</td></tr>
<tr><td><u>Online Questionnaire</u></td><td>Saudi Residents</td></tr>
</table>

4.4 Qualitative Research Method

This research has been conducted in parallel to the quantitative research to authenticate and validate the results using interviews and case studies due to its validity, reliability, and rigorousness. The uniqueness of the qualitative approach is an extension beyond an explanation of facts; however, it focusses on the interpretation of facts and illumination, making sense of the results. (O'Neil, 2002) describes qualitative data as an unconstrained method of phenomena study. There is no agreed definition for this approach as its meaning is diversified due to the various identities it presents. According to (Flick, 2006), qualitative research seeks to analyse both experiences of individuals or groups related to both interactions and communications including analysis of these materials. In addition, documents including texts, images, films or music of experiences or interactions can be analysed and conclusions drawn.

This type of research includes research designs such as interviews, observations and use of photos. (Creswell, 1998, p. 99) states that in qualitative research the subjects tend to be asked "open ended questions, which are evolving and non-directed and most importantly the questions address the "what" and "how" such as "what does it mean to teachers to win an award?"" Qualitative research explores more than just increases and decreases in figures; this form of research, as elaborated by (Achari, 2014) is more concerned with a phenomenon relating to quality or reasons for human behaviour as to the motives to their behaviour, which can be achieved through in-depth interviews.

- **Application of the Qualitative Approach in this Research**

The collection of data in qualitative research is based on exploring individual experiences, beliefs, and motivations through interactions with interviewees. It also includes the use of documents related to the research, yet all this is carried out in the natural environment of the participant. In this type of research method, hypotheses are not formulated at the beginning, which provides the opportunity for the researcher to test the methods which, if not appropriate, can be adapted. Qualitative research enhances the fact that theories should be appropriate to the study. In this research interviews, observation, on-line questionnaire, and photos all represented qualitative data collected, although some questions were quantitative requiring figures. One of the main concerns in conducting this research is the interpretation of the information collected such as texts, writing from observations, field trips and audio transcriptions are presented in the findings.

4.5 Quantitative Research Method

While this research is objective and seen to eliminate generalisations and emphasise specificity, a top-down approach, it is also objective involving the collection and conversion of numerical data. (Achari, 2014) states that quantitative data is based on the measurements, quantity or amounts expressed in figures. Additionally, quantitative research involves a generation of data in quantitative form which can be subjected to rigorous quantitative analysis in a formal and rigid fashion, and which can further be subdivided into the inferential, experimental and simulation approaches. In this approach, specific questions are addressed using questionnaires as well as simulations. The use of questionnaires reiterates the objectivity of the responses and the results from the subjects, as well as enabling the researcher to gather a large amount of data rapidly. The statistics are then demographically represented reflecting information and, finally, the implications of the findings stated. (Denzin and Lincoln, 2005) state how quantitative research is scientific and requires objectivity; however, in this approach, there is a tendency for the research to end up generalising findings abstracting the subject's world. There is an assumption that if methods are used with the same sample, then the result should be the same (Cohen et al., 2000; Hart, 2005).

- **Application of the Quantitative Approach in this Research**

The quantitative data for this research was obtained by means of a questionnaire which was uploaded online and taking of measurements. The questionnaire was structured in such a way which attracted both quantitative and qualitative data. This attracted 261 responses with both numerical data and explanatory data. The question aimed at addressing which operational systems and construction elements contribute to the increase in energy usage. The results were presented on graphs while some transcribed and coded accordingly.

4.6 Mixed Methods Approach

Researchers select a method which aims to answer the research question effectively. However, some researchers prefer using a combination of both the qualitative and quantitative approaches. (Creswell and Creswell, 2017) define mixed methods as the collection and mixing or integration of both quantitative and qualitative data in a given study. (Greene, 2007, p. 20) defines the mixed methods approach as “multiple ways of seeing and hearing”. Furthermore, (ibid, 2007) it is further asserted that the mixed methods approach brings various ways to address a research problem. (Murdaugh, 1999 and Sandelowski, 2000, cited in Stommel et al., 2002) sum up the mixed methods approach as a combination of different methods which is equivalently referred to as multi-methods, mixed methods, or triangulation research. Methodology is vital in the collection of crucial data, and its analysis and interpretation. The collection, analysis and interpretation of data are vital to answer the research questions. Therefore, researchers need to prioritise the importance of the choice of methods and give more consideration to and emphasise the associated perspectives to ensure validity. (Flick, 2018) states that both triangulation and the mixed methods approach are similar in that they use more than one methodological approach.

The combination of both primary and secondary research is valuable to answering the research question, where primary research deals with methods of research such as questionnaires, surveys, and interviews. Secondary research, by contrast, focusses mainly on researched information to inform the researcher of information published about the topic. In this mixed method approach, data is collected using quantitative instruments and qualitative reports through interviews and observations whereby the aim is to ensure the validity of the overall results by comparing those obtained from each of the above perspectives. If the research has analysed and concluded findings from questionnaires, these would then be followed up by explaining the reasons behind the results through interview findings. (Creswell, 2018; Bryman, 2012, p. 41) states that the combination of both qualitative and quantitative methods enables the researcher "to shore up the weaknesses of the other as well as provide confirmation and elaboration". (Bryman, 2012) however, further states that the use of mixed methods is time consuming and also generally costs a lot of money.

4.6.1 Mixed Methods Approach in this Research

In this study, a mixed methods approach will be used to determine the impact of *mashrabiya* on building energy performance and social cultural aspects in the hot climate of Jeddah, Saudi Arabia. In the previous chapters, a critical literature review was conducted into the topics of sustainability and architectural design in order to identify common structural elements and operational systems that may affect energy consumptions in residential buildings. The traditional and modern use of *mashrabiya* was also critically evaluated in various countries with similar climatic, religious, and cultural backgrounds. Quantitative and qualitative methods were selected to reinforce the method of triangulation to ensure validity. Quantitative research is based on information where popularity of issues is the focus with methods such as questionnaires and simulations used for data analysis, whereas the qualitative consists of views and opinions and hence interviews and case studies will provide further explanation for the reasons for certain behaviours or issues.

4.6.2 Techniques of Research Methodology

The data collection techniques are vital in the systematic collection of data for undertaking the research. (Gay et al., 2009, Ousala, 1993, and Olatoye, 2011) state that there are various collection techniques including observations, questionnaire, interviews, test and using available information. The techniques adapted in this research include pilot survey interviews, taking of photos during observations and this was pivotal in the justification of the choice of techniques for this research like the 261 online questionnaires, interviews for both government specialists and 48 residents from Albasateen District as well as photos and measurement taken while observing. Included in the data collection techniques is the villa case study selected from the 48 villas of Albasateen District and the data from this was then used in the simulation process.

4.7 Triangulation

One of the key components to the mixed methods approach is triangulation, which is important not only to validate research findings by generating and comparing data but also confirms the results and ensures their completeness. Triangulation and mixed methods are similar in the use of various types of research methods, however, only differ in that (Flick, 2018) states that triangulation uses broader types of methods, which can be a combination of qualitative methods if so required. According to (Denzin, 1978, p. 291, cited in Krishnaswamy et al., 2006) triangulation can be defined as the combination of methodologies in the study of the same phenomenon. In using two different methods, the assumption is that both will complement each other such that the weaknesses of one can be addressed by the other. Quantitative research methods provide generalised conclusions of the objectives while in the qualitative approach the results are much clearer. (Flick, 2018) is of the opinion that the purpose of using triangulation as a methodological strategy, particularly in social research, is for evaluative purposes. In qualitative research, the combination of methods was mandatory, emphasising the quality of the results. This also involves different researchers in order to validate results as well as to attempt to negate any critique of the results by other researchers.

According to (Mathison, 1988, p. 13, in Flick, 2018) triangulation can be defined as a part of social research that enables the evaluation of conclusions and also, in qualitative research, where the requirement for quality enforces the use of several methods to validate and improve the results. (Bryman, 2012, p. 635) states that triangulation may be required as a result of a planned strategy to check the validity of results, but on the other hand it may be unplanned, yet the results of the research are questionable and need validation, hence another method may be needed. (Mathison, 1988, p. 13, cited in Flick, 2018) reports that the popularity in the use of triangulation was mainly for its convergence or combination of results, their validity and legitimisation of research by other researchers. The rationale behind the use of triangulation in this method was used in conjunction with the justification according to (Bryman, 2012) who support the combination of methods.

An example of triangulation is seen in the work of (Bateson and Mead, 1942) on their study consisting of more than 25,000 photographs, films, paintings, and sculptures. In this kind of approach, data, methods of research, and researchers may be analysed; for example, (Glasser and Strauss, 1964, p. 65, cited in Flick, 2018) introduced the type of data name as slices of data which were collected from multifaceted investigations. In addition, they also highlight the use of various kinds of data while (Strauss et al., 1964:36, cited in Flick, 2018) advocate a combination of different observers to increase the reliability of observations which were made independently of each other.

Triangulation is backdated to the desire or attempt to promote quality, yet its extension in research has proven that it is more than merely combining more than one method. While triangulation has previously been used as a validation tool, the focus now has drifted to that of being more reflective and an extension of knowledge. The mixed methods approach is limited to quantitative and qualitative methods, whereas triangulation transcends application of methods to research perspectives. (Creswell, 2015) states that triangulation strategy has extended further than data triangulation, investigator triangulation, theory triangulation as well as triangulation methods. According to (Creswell, 2015) data triangulation is defined as the use of various sources of data as distinctively as using dissimilar methods in the production of data (1970:301). In support of the above ideology, (Denzin, 2012) notes that this form of data can be investigated by various individuals at different locations and times. In the triangulation of investigators, several investigators analyse the data to check if the researcher has shown any bias in their analysis. (Denzin, 2012) emphasises that in the case of multiple observers being used then only the most skilled observers are entrusted close to the data. For theory triangulation, (Denzin, 2012) states that the method of using theoretical perspectives is one of collecting and analysing data and then evaluating the effectiveness of the perspective to check its suitability.

- **Application of Triangulation in this Research**

This research has adopted a combination of more than one method of research and includes both qualitative and quantitative methods see table (4-1). The quantitative method of research includes the use of questionnaires and taking measurements. In the qualitative approach, observation and interviews are used as methods of collecting data. The researcher interviewed 48 residents in Albasateen district. In addition, interviews were carried out with specialists from four government organisations including Jeddah Municipality (JM), Saudi Electricity Company (SEC), Saudi Energy Efficiency Centre (SEEC) and the Saudi Commission of Heritage and Tourism (SCTNH). The purpose of all the interviews was to investigate the issues of privacy, Hejazi architectural identity, and continuous rise in energy consumption in residential buildings in the city of Jeddah. This research is influenced by various perspectives comprising the constructivist, positivist, and pragmatist views. hence, this research includes the fact that the truth is not absolute but can be verified, and through the interaction with the various individuals involved that the meaning of the world can be revealed, hence the use of mixed methods to validate the findings.

4.8 Overview of Sampling

Researchers select suitable methods to collect data either by using qualitative or quantitative approaches. This could either include observations, interviews, and questionnaires, amongst others. Where participants or respondents are involved, the researcher uses some method to select such participants or subjects. (Thyer, 2010) refers to this method as sampling, which are the methods that researchers use to select the groups, objects, or subjects that they intend to observe. (Thompson, 2012) shows how sampling consists of selecting some part of a population to observe so that one may make estimations about the entire population. (Rubin and Babbie 1997, cited in Thyer, 2010) state how probability samples show a well-presented population and are unbiased in a probabilistic sense. Error can be easily detected through estimation using statistics from samples. There are three approaches to sampling among many that can be used, namely the simple random, stratified random and systematic sampling approaches (Thyer, 2010). (Schaeffer et al., 1996) summarises simple random sampling (SRS) as sample obtained in such a manner that every possible sample of size (n) has the same probability of being tested, which shows the lack of bias inherent to this method. However, in stratified random sampling a list is created from a sampling frame where each population is given a number, then a number table from a computer is used to generate a list of random numbers. The final sampling includes random selection from a stratified sampling population.

4.8.1 Snowball Sampling

In this research snowball sampling was used, especially for the residents' interviews, for several reasons which included cultural differences, where residents show discomfort about allowing strangers into their homes due the privacy barriers, which limits people who are not close to their families to certain rooms of the house. (Noy 2008, cited in Bryman, 2012) points out that in cases where there are barriers to reaching out to certain populations, snowball sampling is crucial. (Bryman, 2012) defines snowball sampling as a method where the researcher first identifies the population group relevant to the research questions. In the second stage of sampling, participants recommend the researcher to other potential participants. (Bryman, 2012) further explains that the entire snowballing process proceeds via reference from one person to another. The increase in number of participants occurs when those nominated further refer others who in turn recommend others. The use of this snowballing method attracted 48 responses from Albasateen district. Each of the subjects sampled represent 48 villas of which one of them was used as a case study. As far as online sampling is concerned, snowballing was also used where the questionnaire was first given to the immediate family and friends who then distributed the questionnaire to close friends until it attracted 261 responses in the whole county of Saudi Arabia.

4.8.2 Questionnaire design

The aim of the questionnaire is to collect data on existing residential buildings in terms of construction elements, operational system, energy consumption, indoor environmental quality' factors, Hejazi architectural identity and *Mashrabiya*. The questions in the questionnaire are divided into six sections, these include:

General Questions: gender, age, No. of family, job, and level of education.

Building Information: The questions require type of home, ownership, date of built, area of both land and house , numbers of floors and facades as well as number of openings on each façade, type of construction material, thermal insulation, glazing and outer finishing.

Air Conditioning information: Type of cooling system, cooling capacity (BTU) of ACs, number of ACs, and the duration of use per day.

Indoor environmental quality' importance and evaluation: Questions on this section rating the indoor environmental quality' factors such as natural and artificial lighting and ventilation, air movement and humidity from 5 the high to 1 which is the lower.

Energy Consumption: This section covers questions on issues like use of AC on each season, preferred set point, number, and type of appliances they have. and annual electricity bills and level of satisfaction,

Residents' privacy and architectural identity: These questions cover the level of privacy and the window treatment used; the next section enquired about identity of Hijazi architecture in residential buildings in Jeddah.

Mashrabiya: the last part of the questions included knowledge of mashrabiya, its functions, reasons for not using it and suggestions for an improved mashrabiya in the future. The detailed questions on the Interview questionnaire can be found in the appendix.

4.8.3 Site Selection

Jeddah was chosen mainly for its location , climatic condition, and the fact that it has Albasateen District which was constructed under government regulations requiring the use of thermal insulation. Secondly most buildings are mainly villas. Finally, it shares the same location and climatic zone with King Abdul-Aziz International airport which is also recognised in design builder. See section 3.2 Why Jeddah.

Figure 4- 2 Albasateen district location in Jeddah (Source: Google Maps)

4.9 Pilot Survey

One of the reasons for completing a pilot study is to eliminate any obstacles to the final study. (Yin, 2016) states that pilot studies help to test and refine one or more aspects of the final study, for example, its design, field procedures, data collection instruments, or analysis plans. The whole process of the pilot study provides the researcher with the opportunity to practice before the final process. Even though this is a pre-run of the real process, it is vital that the participants are informed of the plan (Yin, 2016).

The pilot survey was conducted on a five-day trip to Jeddah city that was made with the intention of interviewing the residents in Albasateen district, which was planned before the visit. The interviews were planned for only three days, approximately a day for each house. All interviews were scheduled for the daytime due to the plan of observing the use of natural lighting. However, due to school holidays, the interviewees changed the pre-planned dates, extending the interview period to five days with a free day in between.

The pilot survey enabled the researcher to protest the interview approach including the questions asked, the management involved in organising appointments and consideration of ethics. The study increased the researcher's confidence on the feasibility of the research design. The results provided guidance on the research methods to be used. The limitations in the pilot survey of lack of understanding from the residents informed the researcher to increase the data collection techniques in order to minimise any differences from one method. The pilot survey confirmed the overuse of air condition by the residents and use of window treatments to provide privacy as a result used artificial lighting instead of natural light.

Figure 4- 3 Three villas for interviewees in Albasateen district, city of Jeddah (Source: Alghamdi, S. 2017)

4.10 Online Questionnaires

Questionnaires have proven to be an effective method of collecting bulk data rapidly and at a low cost. (Cohen et al., 2000) highlight the easy and cheap distribution of questionnaires and the administration of data collection, coding, and analysis. In this research, questionnaires would be distributed to the residents who not only own houses but also have the houses built after August 2010. These houses were built under the government mandatory conditions to install thermal insulation for all new buildings, as stated by the Saudi Electricity Company (2010). On the other hand, it should be noted that questionnaires are limited when respondents respond only reluctantly or, indeed, fail to return a completed questionnaire. According to (Cohen et al., 2000) while large samples of questionnaires could lead to a skewed and distorted set of data in addition the small number of responses received due to low return could prohibit realistic statistical analysis. Due to the above, the questionnaire was piloted before distribution to negate the possibility of any cons-crewed outcomes meaning all the errors identified during pilot survey were rectified. The selection of this method was based on the coverage of a wider scope of respondents. Varied question types were used, particularly open questions, with the intention of verifying ideas from the interviewees' responses.

The purpose of the online questionnaire was to find out which construction elements affect energy consumption in residential buildings. For example, some of the questions required residents to state the type of construction materials, thermal insulation, exterior finishing, and type of glazing used in their homes. These questions were intended to show the relationship between all the above and energy consumption. In relation to the impact of operational systems on energy consumption, residents were asked to report the type and capacity of AC used as well as the AC set point and appliances. Other questions included knowledge, functions and use of *mashrabiya* including the reason for not using them. Residents needed to respond on the expectancy of the future design and material of *mashrabiya*.

- **Procedures for Online Questionnaire in this Research**

This research included online questionnaires which attracted 261 residents from different cities, however, the research area included only Jeddah, in particular Albasateen district. The research expectations were narrowed down to residents who owned and built their villas, leaving the rest of the responses on other questions such as use of *mashrabiya*, level of privacy in their homes and identity of Jeddah. The most important question focussed on whether residents were satisfied with the cost of electricity.

The questions were intended to draw out information such as energy consumption, identity, as well as privacy and *mashrabiya*. These were subdivided into whether the occupants owned, built, or used *mashrabiya* in their property, or if not then to state the reasons why. The questionnaire comprised both open and closed questions. The detailed questions on the online questionnaire can be found in the appendix.

The procedure in the collection of data using the interview questionnaire involved designing the questionnaire, then the selection of questions that would address the objectives such as the impact of structural elements and operational systems on residential building energy performance. These questions were then used during the interviews. By contrast, the online questionnaire included both open and closed questions. This questionnaire was left available online for a period of three months, gaining 261 responses. The responses where then downloaded with information represented demographically.

✓ **Evaluation of Online Questionnaire**

The questionnaire was effective in that a large amount of data was collected within a short period of time. It attracted respondents from various backgrounds for example those who owned, built, or rented their homes. The data also included an area of different types of accommodations; however, some of the responses showed lack of understanding of the questions. In addition, even if the residents were willing to respond accordingly, they had limited knowledge of their building including the area and capacity of their air conditioning (AC) units. Regardless of the discrepancies in the responses to the questionnaire, the researcher believed that the other selected methods of research – the interviews and observations – would complement or infill the gaps.

4.11 Interviews

This method of collecting data is carried out through asking questions that address the research questions. (Hart, 2005) defines interviews as involving interactions with selected respondents on a specific topic to find answers about a specific topic. In addition, (Kvale, 2007) notes that while interviews are considered the major tool for collecting data in qualitative research, he defines them as a specific form of conversation between the interviewer and the interviewee. These interviews are categorised into three subtypes: structured, semi-structured, and unstructured. According to (Silverman, 2000) structured interviews are composed of predetermined questions which are asked with no prompts. As a result, they have the potential to limit respondents from providing detailed responses. On the other hand, unstructured interviews are authentic in nature with no organisation and preconceived theories. The interviewee asks questions from simple to complex where the following questions are dependent on the preceding responses. This may be time consuming as the conversation may lead to digression since it is not controlled. While interviewers can potentially draw much information from the interviewee, there are various difficulties as they are generally time consuming, typically requiring several steps such as booking appointments, translation if interviewees are not literate in English, appointment by reference only, and mahram (chaperon) when necessary. An example relating to this research is that the researcher was aware of the privacy and confidentiality of the information and hence sought consent before interviewing government organisation specialists. In booking appointments, availability seemed to be an issue due to work commitments as some of the interviewees had to go to work. In cases where there was a male respondent, a chaperon was needed hence much time consumed.

This research will focus mainly on semi- structured interviews as this approach is assumed to be effective in exploring the research question. The interviewees will be provided the flexibility to express individual views. It is vital to engage in an interview without any preconceived ideas, as stated by (Cohen et al., 2000) that researchers should avoid having preconceived ideas about the interviewers and their responses. This is likely to show bias and distortion of results. To further elaborate the above ideas, (Cohen et al., op cit) note the need for the researcher to avoid looking for their preconceived answers. Consideration was given for the purpose of acquiring reliable data. One of the advantages of interviews is the detail in the collection of data although there is also the fact that they are time consuming. According to (Hart, 2005) interviews are a detailed gathering method which can generate substantial in-depth qualitative information, usually from a small number of respondents. It is on this basis that a selection of five-six respondents was made for the interview. This has been found to be the most appropriate for this research, and as used alongside questionnaires, interviews have been described as adding depth to breath, as stated by (Hart op cit and Pring, 2000).

The interviews can be divided into three stages which include the pre-interview stage where the research question is clarified, and the project is designed. According to (Silverman, 2000), it is of paramount importance that respondents have some detailed information about the interview in advance. This will provide assurance with regard to safeguarding issues related to anonymity and confidentiality. This is then followed by the process interview where the interviewer and the interviewee interact. The last part is the post-interview phase where the data is transcribed, analysed, verified and findings reported (Kvale, 2007).

There are three groups at which interviews can be analysed, for instance, on the epistemological view, theoretical, ethical, and practical. According to (Kvale, 2007), it is vital that in carrying out interviews that ethical issues are taken into account throughout the process. In all, during the seven interview levels, including thematising, the focus should not be the subject matter concerned, but emphasis should be placed on the benefits of the investigation to humankind. In designing the project, issues regarding the participation of subjects in relation to confidentiality, security and consequences of the study need to be assessed beforehand. The researcher needs to be aware of the conditions surrounding the interview in the Interview situation, for example, stress and misunderstanding of questions. In the audio transcription, confidentiality should be adhered to and, also, the interviewee should confirm the authenticity of the transcribed text. The data analysis should not diverge from the interviewee’s intentions, although it may be difficult to interpret these accurately. In the data verification, the interviewer is expected to be ethically responsible when reporting secure information and should ensure authentication. Finally, reporting information that is confidential to the public should be done with appropriate discretion.

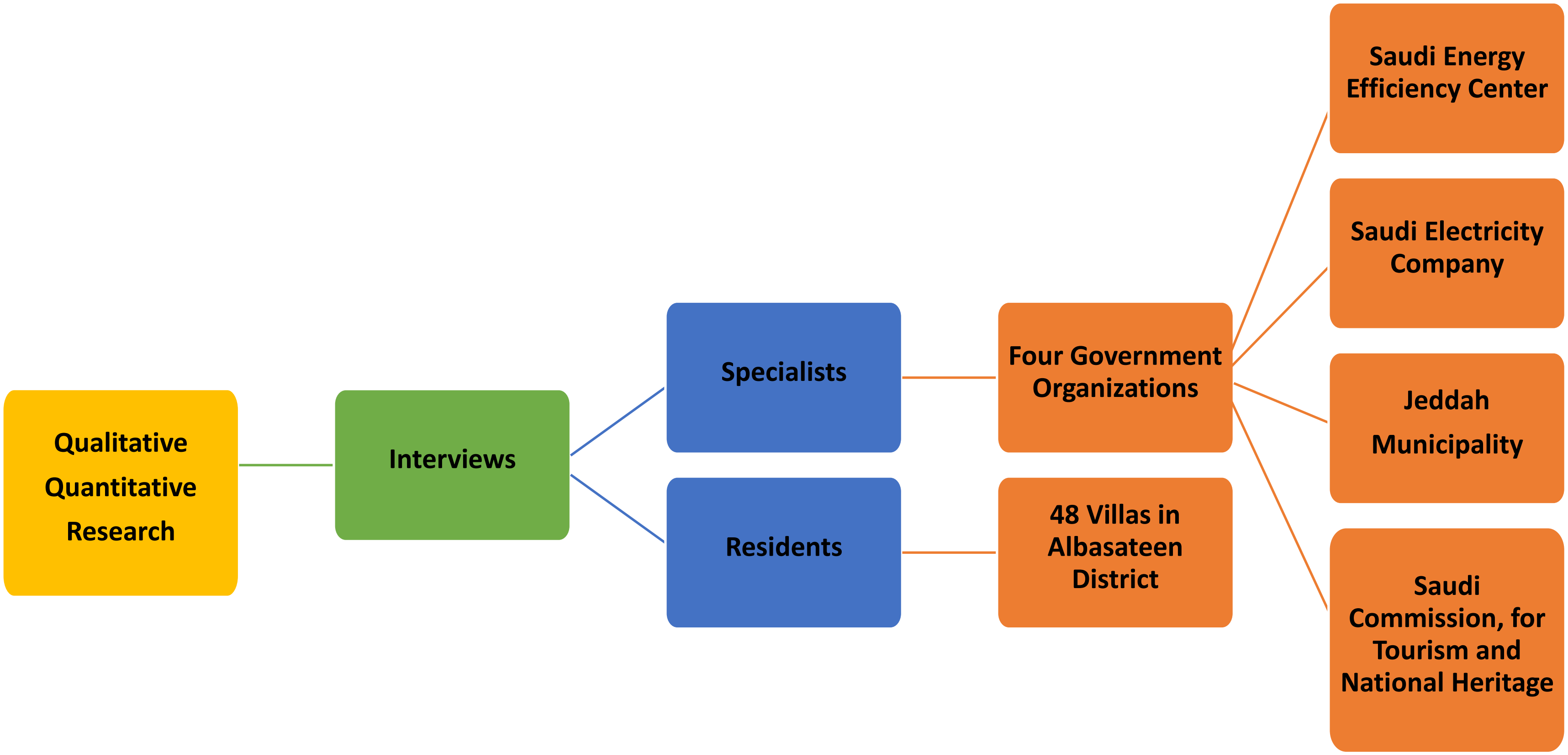


Figure 4- 4 Specialists' and residents' interviews (source: Alghamdi, S. 2019)

- **Interview Procedures in this Research**

Before the interviews were carried out, there were prior arrangements regarding access to organisations and individual homes. This included making applications to Jeddah municipality, Saudi Electricity Company, and the Saudi Energy Efficiency Centre. Other applications were sent to the Saudi Commission for Tourism and National Heritage as well as Albasateen residents. see figure (4-5) which summarised the interviews for both specialists and residents. Since this research involves interviews with higher authorities in highly esteemed organisations, there was a need to ensure that the reason for the research was made clear, and that the information collected would be used mainly for research purposes.

- **Interview Analysis**

When raw data is collected using a variety of data collection techniques, it is not processed, not organised and well-presented but it is only categorised as qualitative or quantitative data. (Taylor and Cihon, 2004) state that this data is further reported in terms of numerical, descriptive, or various combination or both. According to (Guerrero, 2000) data analysis is what data reveals about underlying systems or process from which data is collected. In order to analyse data, several programs are used such as SPSS, Microsoft excel, and more. (Wilkinson, 2000) states that data analysis is carried out at the end of the project when most of the data has been collected.

This research adopted two programs for interview data analysis for 48 residents from Albasateen District. These programs included Microsoft Excel and Statistical Package for the Social Sciences (SPSS). Data was collected using qualitative method of research with open ended questions resulting in long responses that needed transcription and coding also taking much time.

- **Specialists' Interview Procedures**

Additionally, interviews will be conducted with a range of informed parties. In an attempt to assess the cultural identity aspects of existing privately-owned buildings, architects who work for the Jeddah Municipality will be interviewed in order to gather information on practical approaches to the incorporation of *mashrabiya* into modern residential buildings, as well as to gain insights into the effectiveness of *mashrabiya* as a tool to reduce energy consumption. The selection of interviews with architects was based on purposive sampling, hence the criteria are specified which include experience, relevance of latest knowledge in the field of architects, as well as coverage of both past and present ideas in architecture. According to (Vogt, 2012) it is vital to specify the target population and to invite specific members from a pool of potential interviewees to participate. These included Specialists in Electrical engineering and Managing Load and Planning from Saudi Electricity Company (SEC), Director in Management of Energy efficiency Specifications, Head of building team of Saudi Energy Efficiency Centre and Expert in Solar Energy Conservation from Saudi energy Efficiency Centre (SEEC), Planning and development of strategic projects department Director, head of residential projects building permits department from Jeddah Municipality and the Director of Historical Jeddah Office from The Saudi Commission for Tourism and National Heritage.

In relation to the inquiry regarding energy consumption, Saudi Electricity Company (SEC) and Saudi energy Efficiency Centre (SEEC) were interviewed to find out which architectural factors increase energy consumption in residential buildings. On the other hand, a question was posed regarding how operational systems impact on energy performance. The Saudi Commission for Tourism and National Heritage and Jeddah Municipality responded to the question of the loss of identity and functions and the use of *mashrabiya* as well as reinstating *mashrabiya* into contemporary architecture. see Table 5-6 Aspects Investigated Through Interviews with The Specialists in 4 Government Organisations in Saudi Arabia. see table 5-6.

✓ **Evaluation of Specialist's Interview**

One of the positives in dealing with government organisations is the possibility of obtaining authentic data. The results from the research could have an impact in the country if considered effective. However, the challenges included organising a meeting that was suitable for both parties. Additionally, the distance between the organisations meant the researcher had to travel in order to meet the interviewees.

Interviews will be held with residents of privately-owned homes in Albasateen district in Jeddah to assess their privacy and social needs. According to (Bryman, 2016) there is no maximum number in the selection of the interviewees; however, they suggest figures between 12 and 60 for researchers. As a result, 48 participants were chosen for this research. Prior to the interview, consent will be obtained from the residents concerning their participation and willingness to be audio recorded. This data will be supplemented by a case study conducted for a typical villa in Albasateen district in Jeddah. These case studies will closely examine and assess building energy performance using the Dynamic Thermal Simulation tool.

o Procedures for 48 Albasateen District Residents' Interviews

Qualitative information will be obtained from interviews and case studies. The criterion for the selection of the interviewees was based on the location, type of home and ownership. Face-to-face interview was preferred as this is said to achieve the greatest response, as indicated by (Klandermans et al., 2000). Albasateen is situated in the north with temperatures which slightly differ to the south by approximately 3oC. Since the focus of the research is to determine the effectiveness of mashrabiya in terms of saving energy, then this area would be a suitable model to implement the ideas purely by using windows with mashrabiya. Albasateen district was specifically selected due to its modernity and the fact that the homes in the area followed the mandatory policy of insulation by the government. This area consists of two types of homes, namely villas and apartments. The apartments are rented, and hence would not be ideal for the research as tenants have limited rights to make changes in the homes. Ownership is vital in this research as residents had the choice of the architectural elements and, in the future, could renovate homes to suit the discovered and proven ideas in the area of energy reduction.

✓ **Evaluation of 48 Albasateen District Residents' Interviews**

One of the advantages of interviewing 48 residents included consistency in their responses which provided direction towards addressing the objectives. For instance, the questions asked confirmed a lack of privacy and identity. Besides the fact that this method of research is time consuming, it provided an opportunity for the researcher to give further explanation of some questions. The responses from the interviews provided detailed explanation which is not possible with questionnaires alone.

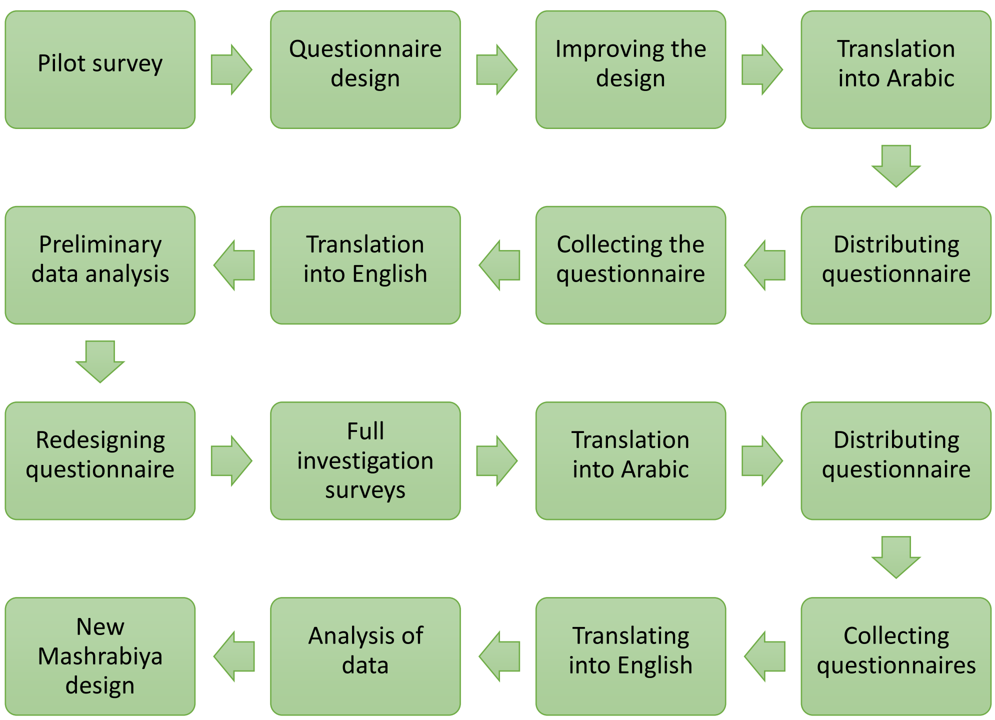


Figure 4- 5 Interview questions procedure (Source: Alghamdi, S. 2019)

4.12 Case Study

Case studies, as a qualitative research method, enhance further explanations beyond mere popularity of figures. This seeks to give further explanations which address behavioural aspects or allow reaffirmation of results. (Consuelo et al., 1992) highlight one of the main advantages of case study as showing patterns of change over a given period as the item interacts with the environment, enabling the researcher to record data from the past and present as well as factors which contribute to change and predictions for the future. There are several types of case studies, where the focus for this research is a villa case study.

Several disadvantages have been documented regarding the use of case studies such as the possibility of overgeneralisation of results where small samples are deployed. (Consuelo, 1992) goes on to say case studies make it difficult to generalise findings or conclusions, especially if done on one particular thing or person. Hence the results from a case study may not be directly applied to other participants (ibid, 1992). This case study has been carefully prearranged following a specified criterion in order to validate the results on specific conditions. The case study for this research involves both personally built and privately-owned villa. Not only should this villa be built in August 2010, it should also possess thermal insulation as well as double glazed window. According to (Denscombe, 2017) a case study may focus on one or more areas that are to be investigated. In this case, the area of research focusses on the window which would be used together with *mashrabiya* if proven effective in not only reducing energy consumption but also providing architectural identity and privacy. The idea behind this method is to eliminate and illuminate the results. (Denscombe, 2017) goes on to state that case study allows the researcher to combine data from research methods such as interviews, documents, questionnaires as part of an investigation to provide the researcher with a holistic view.

- **Case Study Selection**

The case study of a villa was chosen based on the fact that it is located in Albasateen and was built and owned by residents. Additionally, the residents were also cooperative and showed their willingness to provide the necessary requirements for the research, including providing the villa plans which comprised all the construction information. The residents also provided electricity accounts and were flexible towards allowing further observations in the home and the recording of observed areas. The information for the selection is a sample obtained from interviewing 48 residents. The data collected during the interviews for the particular villa would then be inputted into Design Builder for simulation purposes. There are many reasons that contributed to the choice of the villa case study. One of this included openness to providing any information required for the research. The occupants also allowed the researcher access to their electricity account.

- **Case Study and Simulation**

The data would be verified and validated simply through checks as to whether the model functions according to expectations. The computer software would be run several times exposing the model under varied conditions while recording the results. The result would then be used in checking the functions of the model in relation to artificial lighting, natural lighting, operative temperature on the model which would be expected to produce equally the same results on the real building. The villa model in this case study aims at finding out the impact of *Mashrabiya* in serving the needs of the users in the provision of identity, privacy, and energy consumption in Albasateen in Jeddah.

Secondary data from the literature review will be reviewed in the context of the primary data collected from interviews, questionnaires, and the findings from the dynamic thermal simulations. The combined outcomes will then be forwarded to the respective government bodies including Jeddah Municipality, Saudi Energy Efficiency Centre, and Saudi Electricity Company, as well as the Saudi Commission for Tourism and National Heritage in order to make judgements on the reinstating of *mashrabiya* in residential buildings. It is believed that the government organisations will assess and evaluate the performance of *mashrabiya* before making policies on the use of the new architectural element.

Several simulations are run to determine the impact of various aspects of energy performance including lighting, operative temperature, solar gains, and natural ventilation. Simulations were first run using the plan of the existing building which included double glazed windows and the inclusion of air conditioning (AC). The aim of this process was to determine interior indoor environmental quality and energy consumption. The second part of the first stage is to repeat the above process but using natural ventilation (without AC) and with windows partly opened (50%).

In the second stage, a simulation is run with the same villa plan but this time with wooden *mashrabiya* design one (D1) with small holes with and without air conditioning (AC). The purpose of the simulation was to determine indoor environmental quality with *mashrabiya*, as well as understanding energy performance, solar gain and natural lighting and ventilation. The second part of the second stage of the simulation included using wooden *mashrabiya* design two (D2) with large holes with and without air conditioning (AC) in order to detect changes in the indoor environmental quality and compare both designs in relation to energy consumption, solar gain, natural lighting, and ventilation, then select the more effective design.

The final process included replacing the wooden material *mashrabiya* (D1) and (D2) with gypsum then determine the differences in indoor environmental quality and energy consumption.

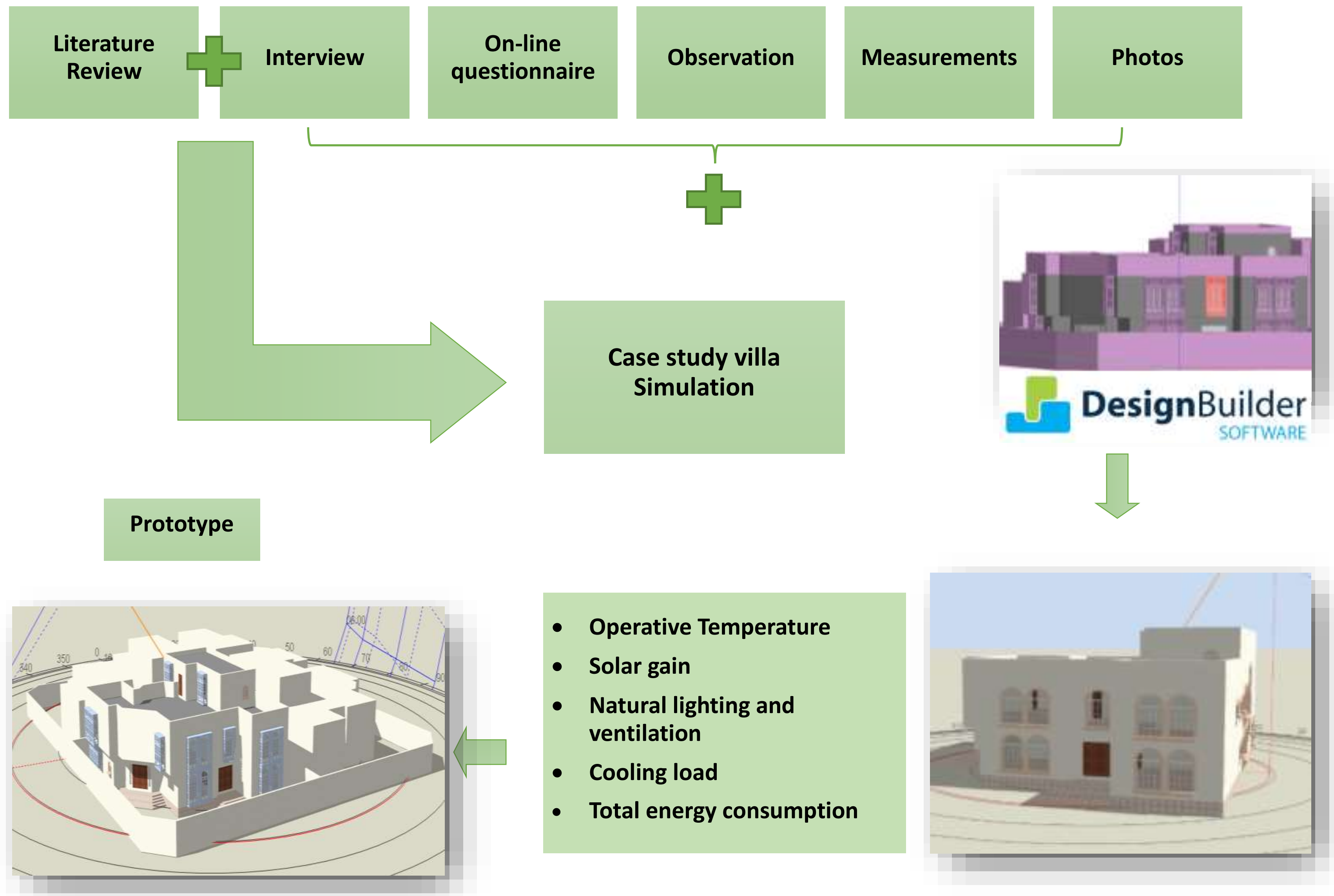


Figure 4- 6 Structure of research methods and techniques (Source: Alghamdi, S. 2019)

4.13 Overview on Design Builder (Energy Plus) and Simulation

This approach was chosen to address the question of the reduction of energy consumption using *mashrabiya* in Jeddah. This would follow the collection of data from both quantitative and qualitative research, which would be then analysed, and the results used to inform the program that would design a model of an imaginary villa design using computer aided design software. This software namely design builder was chosen for several reasons including its efficiency, reliability, and accuracy. In addition, design builder is dynamic because it integrates energy plus making it dynamic for thermal simulation. It is accurate in terms of data related to energy consumption, indoor environmental quality, and solar gains. (Davis et al., 2007, p. 481) defines a simulation as "a method for using computer software to model the operation of the "real world"". The idea behind this approach is to investigate concepts of interest and to visualise the model, its functions and behaviour in the real world. Simulation is an easier option to investigate concepts using Design Builder that would otherwise be complicated, costly, and even impractical under normal circumstances. Due to the nurture of the investigation, the results for the real building may be inferred.

One of the advantages of using simulation is the fact that it eliminates problems which may be encountered if alterations were to be made to existing structures. According to (Anu, 1997, cited in Rapport, 1999) there are 10 stages which may be followed in simulation although not all of them may be followed depending on the nurture of the investigation. These stages include identification of the problem; in this case, continuous increase of energy consumption has been identified as a major problem in Saudi Arabia with Jeddah identified as an appropriate area of study. This is followed by the formulation of the problem, and the researcher narrowed down the research to one architectural element, namely the window. The investigation aims to determine the impact of *mashrabiya* in a hot climatic area of Saudi Arabia. The data collection phase is where this data is then analysed, and results inputted in Design Builder as input variables to develop a model, which represents the fourth step. The fifth phase is the configuration or validation stage in that the test simulation results are expected to be similar to the real-life building. If the simulation process matches similar conditions, then the final outcome is highly likely to be representative.

In the next stage is the decision regarding the experiment based on mashrabiya design and material to check its impact on building energy performance. This is followed by simulation runs with conditions addressing the objectives of the investigation, where for this research would be reduction of energy consumption, improving of natural lighting, and ventilation. The ninth stage is the actual simulation runs which lasted for a few hours each over a period of a number of days. The final stage is the interpretation of the results, which are demographically represented, followed by sharing of the results with the respective organisations and offering further recommendations for research. The villa model will focus mainly on the window and the expectations with regard to presenting identity as well as privacy and the reduction of energy consumption.

- **Procedure for Simulation**

Entry information for the Design Builder software will be calculated following the characterisation of one villa case study selected from the 48 villas in Albasateen District. A range of simulations will be then conducted to evaluate energy performance of *mashrabiya* for the case study villa in terms of lighting, thermal analysis, and indoor environmental quality. Additionally, the optimisation will be tested to create a proposed set of interventions that could reduce energy consumption for different *mashrabiya* designs. The main aim of the simulation is to investigate the impact of mashrabiya on building energy performance focusing on the factors that affect energy consumption such as natural and artificial lighting and ventilation, solar gains, and cooling load. in order to achieve the results on the above areas, data was inputted from the selected villa case study as well as all the data from table 6 -7. After building the model using the data from the case study villa the next stage is to identify fixed aspects of the model such as weather data, AC type and constructions materials.

In order to ensure the accuracy and validity of the results this stage included calibration process where the villa case study was simulated as it is in order to comber the simulation results with the real villa case study. Then start simulation using factors stated above. In the fifth stage includes analyses of results. Further information on simulation see chapter six (6.5.1).

Evaluation for simulation

One of the advantages of simulation is that it provides results close to real buildings. Another advantage is that it is clearly cheaper and quicker compared to building a real home for investigation. Finally, it allows further investigations on the effect of different parameters on comfort, energy performance and more. While the negatives of the simulation program in Design Builder is that it takes longer to calculate the results because of the many parameters that need to be simulated. One other issue about Design Builders is the fact that it uses Energy Plus, which is not compatible with drawing architectural elements, so it takes a long time to draw example *mashrabiya* as this requires drawing one part at a time.

4.14 Research Limitations

Interviews are generally time consuming, typically requiring several steps such as booking appointments, translation if interviewees are not literate in English, appointment by reference only, and mahram (chaperon) when necessary.

- The researcher was aware of the privacy and confidentiality of the information and hence sought consent before interviewing government organisation specialists.
- In booking appointments, availability seemed to be an issue due to work commitments as some of the interviewees had to go to work.
- In cases where there was a male respondent, a chaperon was needed hence much time consumed.

- Traditional buildings in Al-Balad have tight security, hence accessing these places requires documentation of approval. In addition, the opening times are dependent on the specific festivals which means any other day may not be suitable to enter.

- Online questionnaire and semi- structured interview questions were structured in English; however, these were translated into Arabic for understanding and reduction of complications. The final stage of the interview included the translation of the responses from Arabic to English which meant some of the meaning could have been lost in the process. The whole process proved to be time-consuming.

- Having to travel between the country of study (United Kingdom) and the research area (Saudi Arabia) made the collection of data difficult, as well as incurring considerable expenses.

Below are limitations from the pilot survey.

- The interview process had several obstacles, such as direct contact with residents. This meant the arrangement was only by recommendation. In the instance of interviewees participating as couples, there needed to be a chaperon, that is, one relative had to be part of the team for privacy and accountability purposes.

- Privacy and cultural protocols made it difficult to access people's living rooms as this would mean breaking into another level of privacy which only close members of the family can normally access. There was a greater need to access this room, which meant being allowed and that the associated level of privacy had to be bridged.

- The interviewees were not well informed, for example, about the capacity of AC, type of construction material and area of the building. This meant that the results provided were not always logical.

4.15 Ethics Report

The research complies with the Faculty Ethics Committee which follows not only the UK laws but ensures all research carried under DMU supervision is compliant with the regulations and promotes its best Practice. (see the Ethical approval forms in Appendix: A,B,C,D and E). This research promotes data protection and identity of participants. Before carrying out the interviews and observations, the participants consented and were assured of confidentiality, protection, and usage of data. After the transcription of data, the participants confirmed the authenticity of transcribed data. The ethics issues were addressed according to the Faculty Ethics Committee and checklist of the Faculty of Art, Design and Humanities (A,D&H). Checklist completed in December 2016.

4.16 conclusion

Research results are as crucial and valid as the methods of research used and the achievement of its objectives. The quality of the research can be measured by the relevance, knowledge, and status of the participants to the research topic. The who in this particular research includes the residents who not only owned but also built their villas. It also extends to the four government organisation architects. These groups of people offered an excellent opportunity for the researcher to investigate three aspects of such housing including energy consumption, identity, and privacy, with Saudi Electricity Company (SEC) and Saudi energy Efficiency Centre (SEEC) providing the information needed to determine energy consumption while the Saudi Commission for Tourism and National Heritage dealt with aspects of identity and privacy which would include the reinstatement of *mashrabiya*. Finally, Jeddah Municipality (JM) participated in all three of the research aspects already mentioned above. It is hoped that when the analysis has been completed the results will be shared with these government organisations, who have the authority to make and implement policies relating to the subject areas under investigation.

The research topic matters, as its importance has the potential to change a situation, an environment or individual circumstances depending on the research theories and the epistemological consideration of truth. The investigation into the topic under discussion will affect the people first and then the environment. The topic focusses on the reduction of energy consumption in a hot climate although the area of research is Jeddah, Albasateen District.

The research is based on the constructivist, positivist, and pragmatist perspectives. Having the positivists' perspectives provides awareness of the fact that the truth is not fixed, hence the ambition to research the use of *mashrabiya* in the hope of finding new information that will be useful not only to the environment but also people. One of the disadvantages of this perspective is the possibility of the research falling into error and returning results which may not be used in any situation, resulting in a waste of time and resources.

On the other hand, the constructivist point of view shows that through interaction with the world individuals find meaning behind issues. This perspective has been adopted in this research with the intention that there is more to *mashrabiya* that is still to be discovered than already has been. This mentality motivated the researcher to carry out this investigation to determine the effectiveness of *mashrabiya* in terms of reducing, to some extent, the continuous increase in energy consumption. While the researcher is likely to discover new information, it is possible that during the process unproductive information may also be rediscovered.

Another worldview that has been used in this research is the pragmatists' interpretation for its simplicity and the focus on the results and not the associated procedures. This perspective was used to validate the authenticity of the results, providing the researcher with various avenues to approach and analyse the issues related to the rise in energy consumption, deterioration of identify, and lack of privacy in Jeddah's architecture. These views extend to the use of the mixed methods approach, and hence the qualitative and quantitative methods have been used for this research in order to validate the results. The way data is analysed is dependent on the researcher's perspective and demographic presentation of data reflects the methods used in the research.

It should be noted that these research methods were adapted in the research in a particular order including online questionnaire, specialist's interview, Albasateen residents' interview and observation as well as taking measurements and photos for specific reasons in the collection of data. Firstly, the online questionnaire was conducted with the purpose of bulk collection of data however, when data showed some discrepancies then interviews became an alternative that would validate the results. In parallel with the interview's observations were carried out while photos and measurements taken. The following chapter shows the data collection using these research methods.

CHAPTER FIVE

5. Data from On-line Questionnaire and Interviews

5.1 Introduction

This research follows a mixed method study which combines both the qualitative and quantitative approaches for the purpose of validation, complementing and illumination of the results. One of the strengths in the use of the qualitative approach is based on the advantages of using a natural setting with participants in order to investigate critical concepts relating to the organisations or individuals. The researcher opted to interview specialists from four significant organisations in the Kingdom of Saudi Arabia which include the Saudi Energy Efficiency Centre (SEEC), the Saudi Electricity Company (SEC), the Saudi Commission for Tourism and Natural Heritage (SCTNH) as well as Jeddah Municipality (JM). These organisations were carefully selected not only for the vital role they play in the country but also to address the aim of investigating issues related to energy consumption, social culture (for example loss of identity and privacy in Jeddah), and also finding out through simulation whether *mashrabiya* would reduce energy usage in a villa. The results obtained from the research, if deemed satisfactory to the organisations, would be implemented as a major change in the Kingdom of Saudi Arabia. The four leading organisations work in collaboration with 30 other government organisations, yet individually they function very differently.

The online questionnaire was another form of enquiry used to collect data comprising open, closed, and multiple questions see figure (5-1). According to (Czaja and Blair, 2005) in open-ended questions the respondents tend to express their opinions in their own words. One of the advantages of open-ended questions is the ability of respondents to express their attitudes and how they feel, showing a detailed and in-depth response to the topic in question. The questionnaire also included ranking the questions in order of significance as well as the dichotomous type. This provides researchers with a clear understanding of the respondents' perceptions of the subject. On the other hand, while the closed questions are limiting in nature, they do lead to specific responses. (Czar and

Blair, 2005) define closed questions as a list of responses that the respondent simply chooses from.

Type of questions

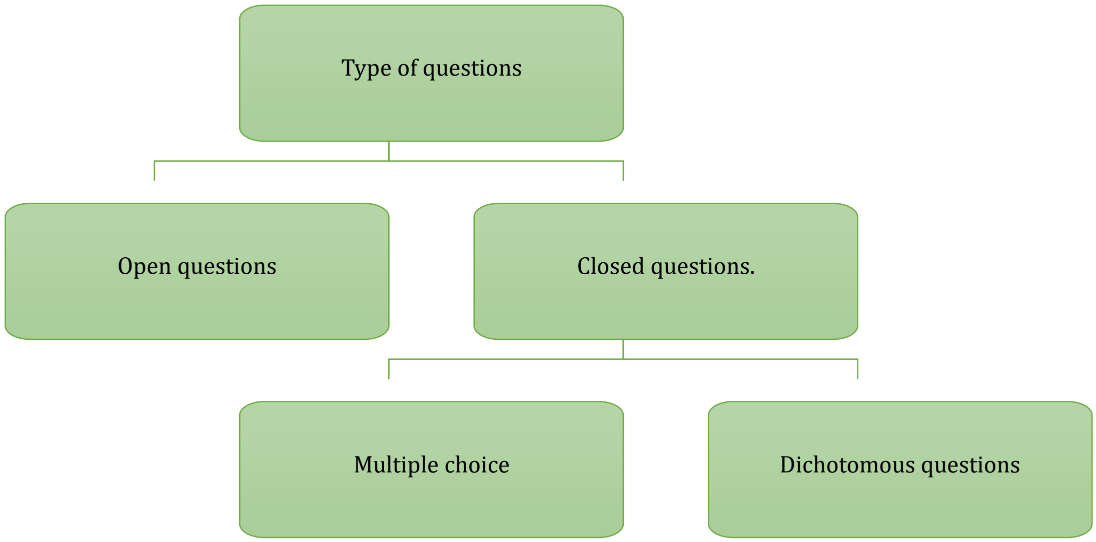


Figure 5- 1 Types of questions used in data collection.

5.2 Online Questionnaire

Prior to the online questionnaire a pilot survey was carried out taking much time approximately one month including the whole process for making arrangement for only three villas. The online questionnaire therefore aimed at not only a wider range of participants this also focused on the fact that it is the quickest way of collecting data. The questions were designed to draw information about building for example construction material, thermal insulation, type of glass windows and number of facades. This also included number of storeys and operational systems. In addition, the content of the questions targeted level of privacy and knowledge and use of mashrabiya.

However, due to limited information on some of the responses, the researcher opted for interviews in Albasateen District as the online responses were not clearly elaborated. The responses demonstrated a wide range of views with some responses not valid while others proved to be more suitable regardless of the area of research selected.

5.2.1 Justification of the choice of participants

The results below show responses from online participants. The information collected shows the demographics of participants to three questions regarding gender, age, and level of education. The results from mixed sexes are expected to provide different gender viewpoints whilst the level of education would validate the results, ensuring respondents understood the questions and responded both critically and with understanding. The ages represented a diversified range which brings not only academic knowledge and experience from different age levels but also life experience to approach to life to the research.

- ***Gender***
- ***Age***
- ***Level of Education***

The total number of participants by gender totalled up to 69% and 31% females and males, respectively.

Table 5- 1 Group categories

Age group	20-30	31-40	41-50	+51
%	58	23	10	9

The different age groups involved in the research included four categories, from 20 to 51 with the highest being 58% between 20 and 30. While those between 31 to 40 reflected a sample size of about half the previous age group with a proportion of 23%. In addition, those in the 41 to 50 group totalled 10% of respondents, while the 51+ group totalled 9% of the participants.

The results show the participants with various levels of education including the undergraduate to the doctorate level; however, there are also a small proportion with no highest level of education. It is clear that a total of about 66% included those holding an undergraduate level education while the lowest, totalling up to around 6%, was for the doctoral-level respondents. Four times fewer respondents held a master's qualification than an undergraduate one.

- ***Location***

The online questionnaires targeted Jeddah and mainly Albasateen District residents as the main questionnaire focusses on the impact of *mashrabiya* in hot climates. The number of responses increased beginning with friends and family snowball sampling further by recommendations. According to the results, the questionnaire attracted responses further than Jeddah about 69% since these were online. However, there is the reasonable number of responses from Jeddah itself, totalling up to 31%, which is a good representative sample for data analysis. Within the 31% of the respondents, these include 14% from Albasateen and five other districts nearby sharing similar building characteristics and climatic conditions.

5.2.2 Building Information

- **How many numbers of facades does your house have?**
- **How many people live in the house?**

The information provides the total number of facades that each house has from one and four. It is clear from the data collected that most residents admit having one façade a total of 49% and the least number of respondents 8% have four facades while 14 and 29% of the results show a total number of three and two number of facades, respectively. The results revealed the total number of occupants in the house from a range of 2-4 people, 5-7, 8-10 and 11 and above. According to the results, the highest figures are of those between five to seven occupants, totalling almost 55%. The figures vary from around 2% to as high as more than 11 people. The range between two to four occupants have a percentage of 31 and are the second highest. Number of occupants between 8 and 10 are, proportionately, 12%.

Table 5- 2 Number of occupants

NO of occupants	2-4	5-7	8=10	+11
%	31	55	12	2

- **what is the type of your house?**
- **Do you own the house?**
- **Did you build your house?**

The following are responses from the three questions listed above. The results indicate that 43% of the residents live in an apartment while about 48% live in villas; the remainder totalling to 9%, live in a type of house that cannot be categorised as either a villa or apartment. On the question of whether the residents owned or rent the homes, 64% of them stated that they owned their homes while only 36% rented. regarding whether the residents built their homes 35% confirmed they built their homes while 65% did not. Even though the responses above show that residents built, owned their villas which is the focus of the research, the figures are very small to make conclusive decisions in some research areas hence another method of data collection was adopted to validate the results.

- **what is the age of the building?**
- **how many years have you lived in the current house?**
- **how many storeys in your home?**
- **What is the total area of your house?**

The following question was asked based on the government regulations regarding building thermal insulation which means that if the age of the building is below 10 years in this case from 1-10 would have been insulated. this research focused on buildings that are insulated or built after the government regulation in 2010. On the question of the age of the building the responses are divided into five categories with ranges from 1-5, 6-10 and 11-15 as well as 16-20 and 21 and more. According to the results, 24% is the highest on the newest buildings between 1-5 years followed by 6-10 years with a percentage of 22 making the two ranges with a total percentage of 46. The building with the age range of 16 -20 and 21 and above show 16 and 17% respectively a total percentage of 33 altogether. The houses in the age range of 11-15 have a percentage of 21.

Table 5- 3 Age of the building

Range	***1 -5 years***	***6 – 10 years***	***11 – 15 years***	***16 -20 years***	***21 and more***
%	*24*	*22*	*21*	*16*	*17*

On the year's residents have lived in their house, the responses show a total of about 51% who have lived in their current home for less than 8 years while 49% of the participants have lived in their current home for more than 8 years.

On the question related to the number of storeys the results show that 43%, which also represents the highest percentage, of homeowners have three storeys while the lowest is for those with six and ten storeys, at 3%. The second highest figure, which is approximately 31%, is that proportion living in buildings with two storeys. Those living in 1 and 5 storeys are represented by 12%.

Table 5- 4 Total house area

Area	**0-200 m^2**	**201-500 m^2**	**500-1000 m^2**	**1001+ m^2**	**Do not know**	**No response**
NO of houses	**15**	30	40	7	6	163

The table above is a representation of the responses to the floor area of the houses of the respondents. The results in the table show a lack of understanding of the question as some of the figures reported seem unrealistic. For example, the total area on some of the figures recorded include 0 square meters, 7, 12, 15 and 40 which are incorrect for the area of a standard home.

5.2.3 Construction Details

- **Did you use thermal insulation in your house?**
- **Which part of your house is insulated?**
- **which materials did your use to build external walls?**
- **what type of glass did you use in your windows?**

On the question of whether residents use thermal insulation in their homes, about 55% state that their homes are insulated while 45% live in uninsulated homes.

The bar chart below shows the responses to the type of insulation that residents have used in their homes. As reflected in the diagram, the highest percentage is for those whose exterior walls are insulated. The second highest figure is for the homes with insulated roofs and, finally, 31% have highlighted other to state a part of building which is insulated but not mentioned in the options above.

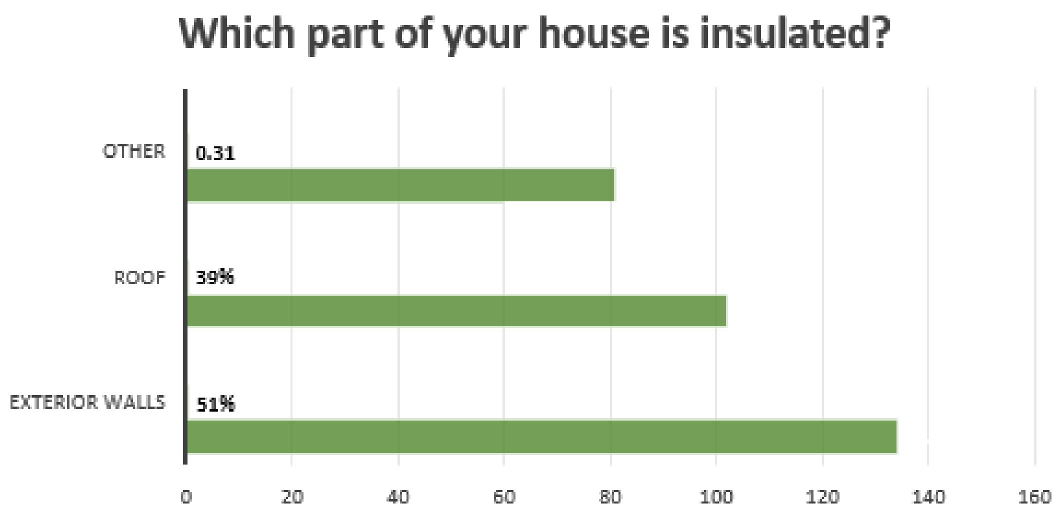


Figure 5- 2 Insulated parts in the house.

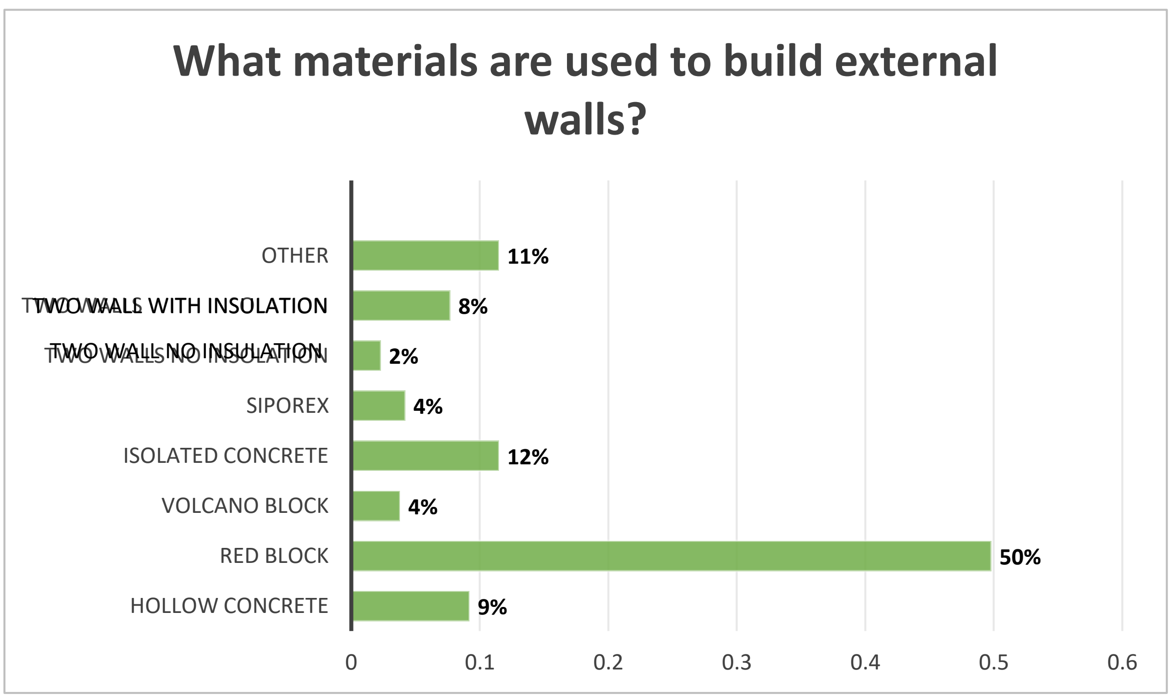


Figure 5- 3 Type of material used for external walls.

The bar chart shows the types of materials residents used to build the external walls from a list of seven including hollow concrete, red and volcano block, as well as isolated concrete and Siporex block. Residents also had a choice of using two walls with and without isolation, and others not listed above.

On the question of the type of glass that residents use in their homes, given a choice of three including single, double, and treble glazing and other, the majority of residents with a total percentage of 59 stated that they use double glazing type of glass while 33% mentioned using single type and the lowest included those who used treble glazed windows and the rest selected other as the type of glass.

5.2.4 Energy Consumption

Operational systems

- **Do you have any air-cooling system in your house?**
- **how satisfied are you with the cost of electricity bill?**
- **How is the cost of electricity bill annually?**

The results show the percentage of residents who own air conditioning systems in their homes. It is clear that 83% have air conditioning systems while 17% claim not to, though the latter is highly unlikely given the climatic conditions in Jeddah. This may be due to lack of understanding of the question. Those who responded negatively may not have understood the question as most Saudis use AC for indoor.

On the level of satisfaction regarding the cost of electricity. The results indicate that 69% of residents are not content with the payment towards the electricity bill. On the other hand, 31% claimed to not have any concerns regarding their electricity bills.

Table 5- 5 Annual cost of electricity bill

Annual cost of electricity bill							
SR	Less than 5000	5000-10000	10001-15000	15001-20000	20001-25000	25001-30000	More than 30000
%	37	37	14	7	1	3	1

In response to how much residents pay annually towards their electricity bills; the table clearly shows the highest percentage of people totalling up to 74% almost three quarters who pay within the range of 10 000SR and below indicating that the majority of the people were extremely affected by the increase in tariffs.

- **What type of Air Conditioning do you have?**
- **what is the cooling capacity (British Thermal Units) Btu/hr of the AC?**

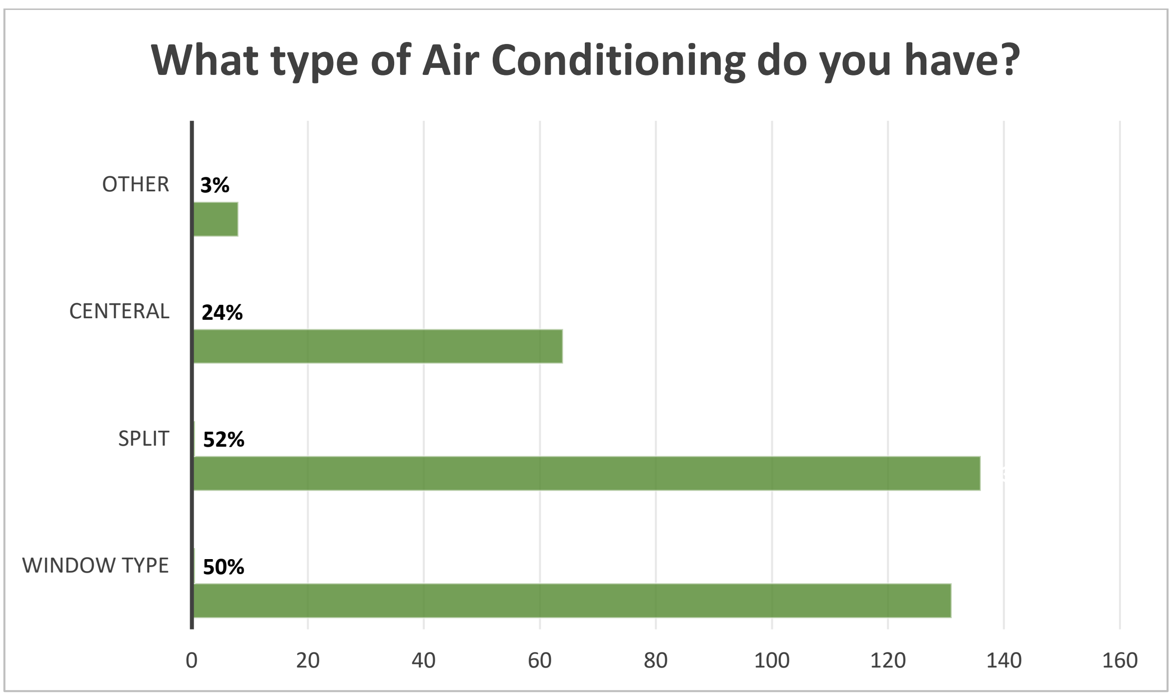


Figure 5- 4 Type of air condition

The bar chart shows the responses to the type of air conditioning that residents use in their homes. As shown in the diagram, the majority of the residents use the split air conditioning type followed by those using window air conditioning, with proportions of

52% and 50%, respectively. In third position is the proportion of those who use central air conditioning with a proportion of 25%, whilst only 3% claim to use other types of AC than those listed above. according SEEC the split and window type air condition are less energy efficient compared to the central AC emphasising the increase in energy usage in residential buildings.

Table 5- 6 Cooling system capacity

If you use air conditioning, what is the cooling capacity in Btu/hr of the unit?				
0-250	250-1000	1000-4000	I do not know	No response
34	48	9	6	164

The table above shows the responses of residents regarding the cooling capacity of the of their AC type, which demonstrate a range of discrepancies as residents seem to have failed to understand the question, hence the results are off the mark.

- **When do you use the AC the most?**
- **Daily usage of AC in the living room**

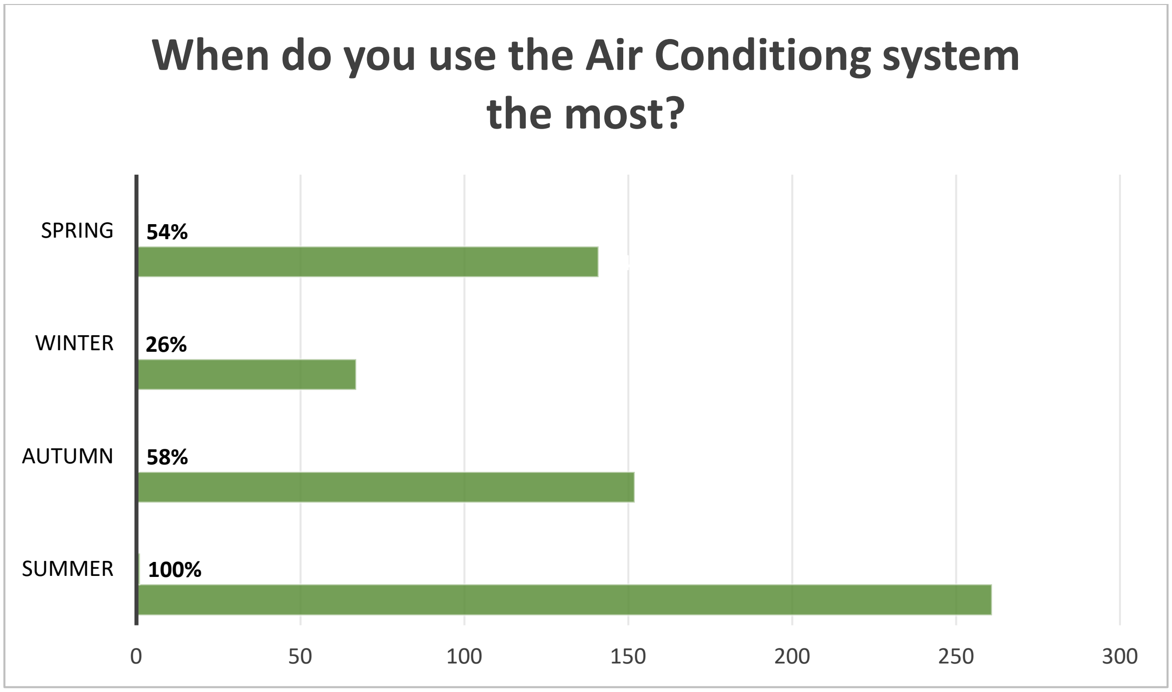


Figure 5- 5 When air conditioning is used the most.

The bar chart above is a representation of the responses to the season when the air conditioning is used the most. It is clear that most residents use the air conditioning in summer (with a percentage of 100%) while winter has the lowest percentage usage (at about 26%). Autumn and spring have almost the same percentage usage of air conditioning at 58% and 54%, respectively. The results indicate the possibility that the 26% of the respondents avoid using natural ventilation to cool the interior in winter.

Given four choices of times of the daily usage of AC in the living room, which include less than 6 hours between 6 to 12, 13 to 18 and 19 to 24 hours. The results show that AC is mostly used between 0 to 6 which is 58% followed by 6to 12 hours with 23% both durations result in a significant figure of 81%. It is interesting to note that the higher the number of the usage of AC, the lower the number of people which is 10% and 9% for 13 to 18 and 19 to 24hours.

5.2.5 Privacy

The responses from the questions listed below aim to address the question of whether residents have privacy. This will also validate the results by checking residents' claims to find out if they use other methods to enhance privacy. If residents use other methods to enhance privacy, this will demonstrate a lack of privacy in their homes and hence the adoption of other approaches to addressing this issue. The questions also seek to show the most popular window treatments that residents use to increase their levels of privacy, when relevant. According to the responses it is apparent that residents use curtains and blackouts as well as shutters and trees to enhance their privacy.

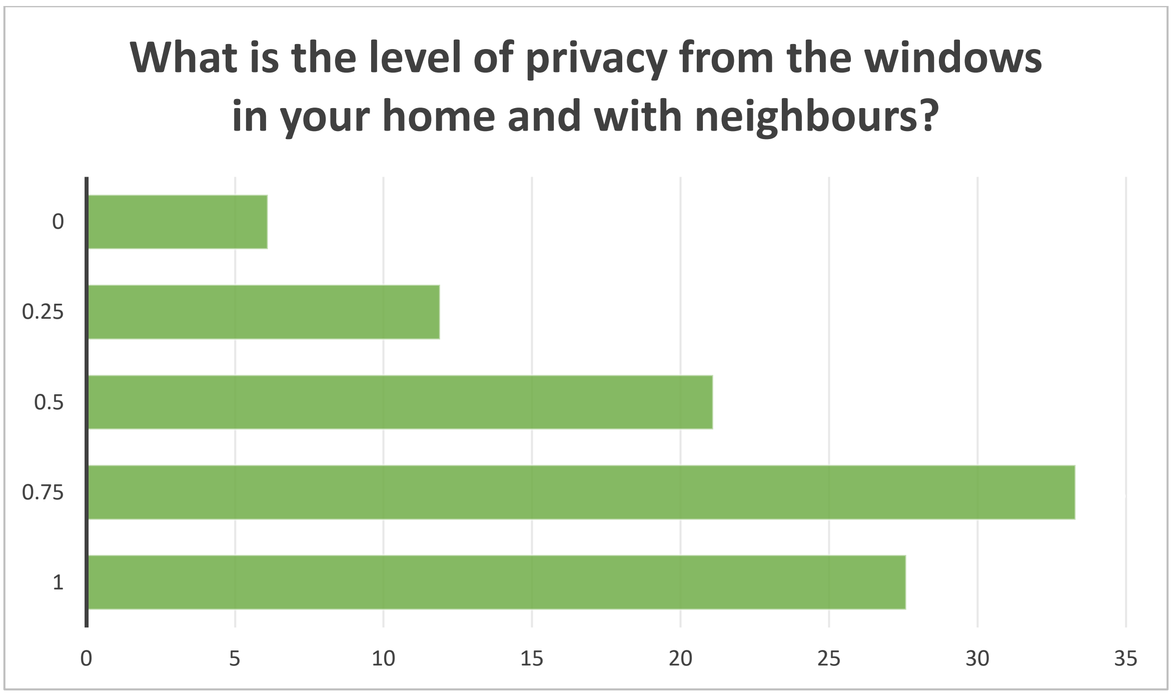


Figure 5- 6 Level of privacy

The diagram shows five categories of levels of privacy beginning from 0, 25,50, 75 and 100%, and with the choices of the residents reflecting the levels of privacy in their homes. According to the diagram, it is clear that a third of the respondents highlight the fact that they experience only 75% privacy in their homes, while those who claim to have

100% privacy total approximately 28%. A fifth of the respondents profess to having 50% privacy, whereas the lowest proportion, about 6%, is of the opinion that there is no privacy at all in their homes.

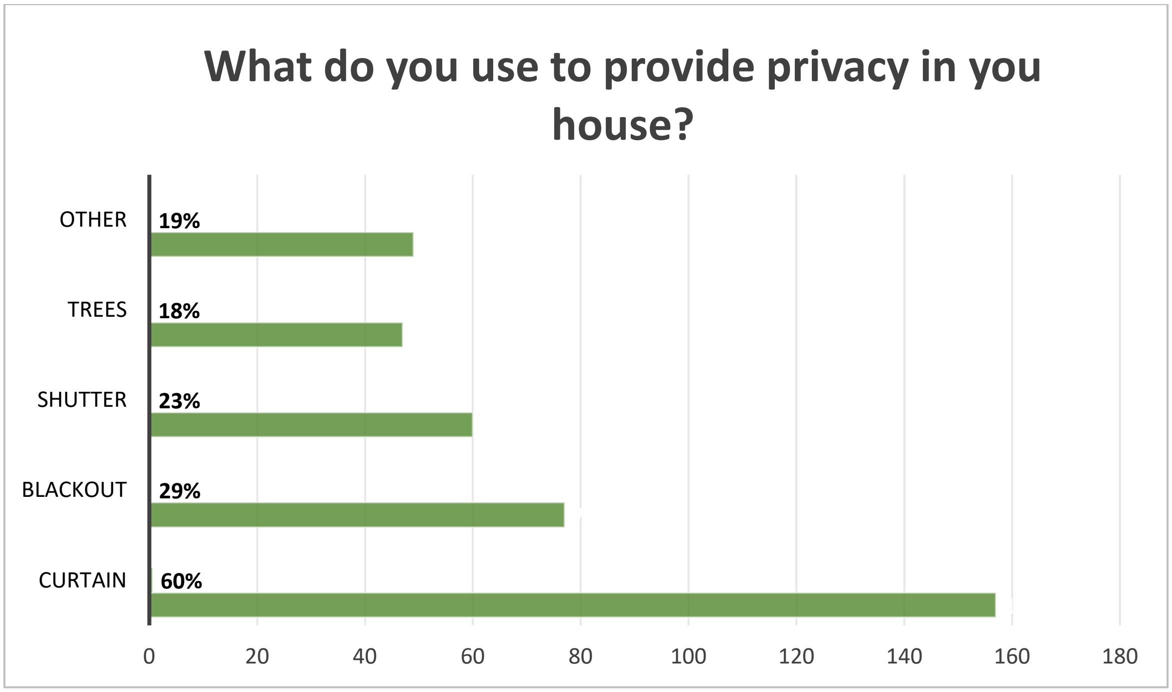


Figure 5- 7 Window treatment to provide privacy.

The diagram demonstrates the ways used by residents to provide privacy. The majority of the respondents claim to have a certain level of privacy except that it varies from 0 to 100%. A total of about 6% from the previous question assert that there is no privacy in their homes. The diagram clearly indicates that regardless of claims made about the level of privacy in the respondents' homes, most residents use some form of protection at the window or around their house to enhance privacy such as curtains and blackouts as well as shutters and trees. A total of about 60% residents uses curtains to increase the level of privacy in their homes, while the lowest percentage, of around 18%, is for respondents who rely on trees as a form of protection from passers-by. Close to 18% of residents use other methods to increase their level of privacy other than the ones listed above. 30 and 23% of homeowners use shutters and blackouts, respectively.

5.2.6 Mashrabiya

Included in the online questionnaire are five specific questions which sought out to find out if residents had not only the knowledge of *mashrabiya* but also its functions. The questions further checked if respondents used this architectural element and if not to state the reasons. Finally, residents had the opportunity to contribute to the design of the future modernised *mashrabiya*. On the question on whether residents have any knowledge of what *mashrabiya* are, the results clearly indicate that almost 72% of the respondents are aware of what *mashrabiya* are but almost 28% seem to have no knowledge of them at all.

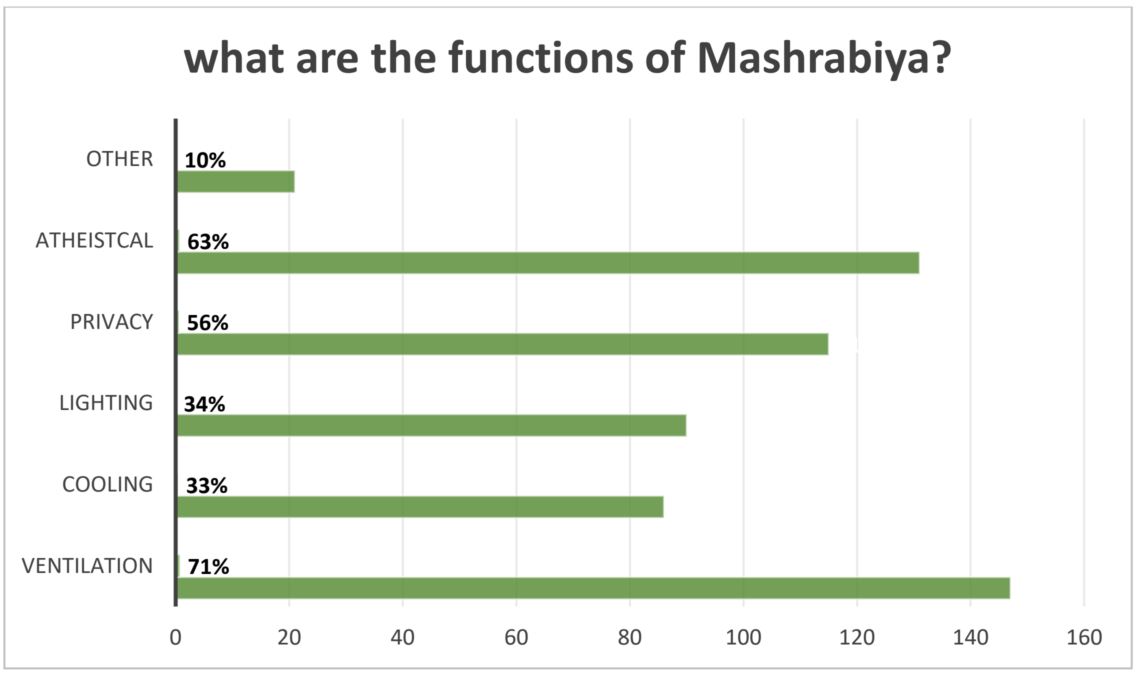


Figure 5- 8 Mashrabiya functions

The bar graph above represents the knowledge of residents regarding the functions of *mashrabiya.* The residents showed their understanding by ticking options from the list provided. The graph clearly shows the highest proportion, 71%, pointing out that *mashrabiya* are used for ventilation purposes while the lowest proportion, 41%, believe that *mashrabiya* are mainly used for cooling. The second highest percentage assert that *mashrabiya* are valuable as decorative features while about 56% note their privacy aspect.

In relation to lighting, about 44% of the respondents stated that *mashrabiya* allow lighting. About 10% of the respondents seem to have other reasons apart from those listed above. According to the results on the question of whether residents use mashrabiya almost 96% do not use mashrabiya while only 4% use mashrabiya.

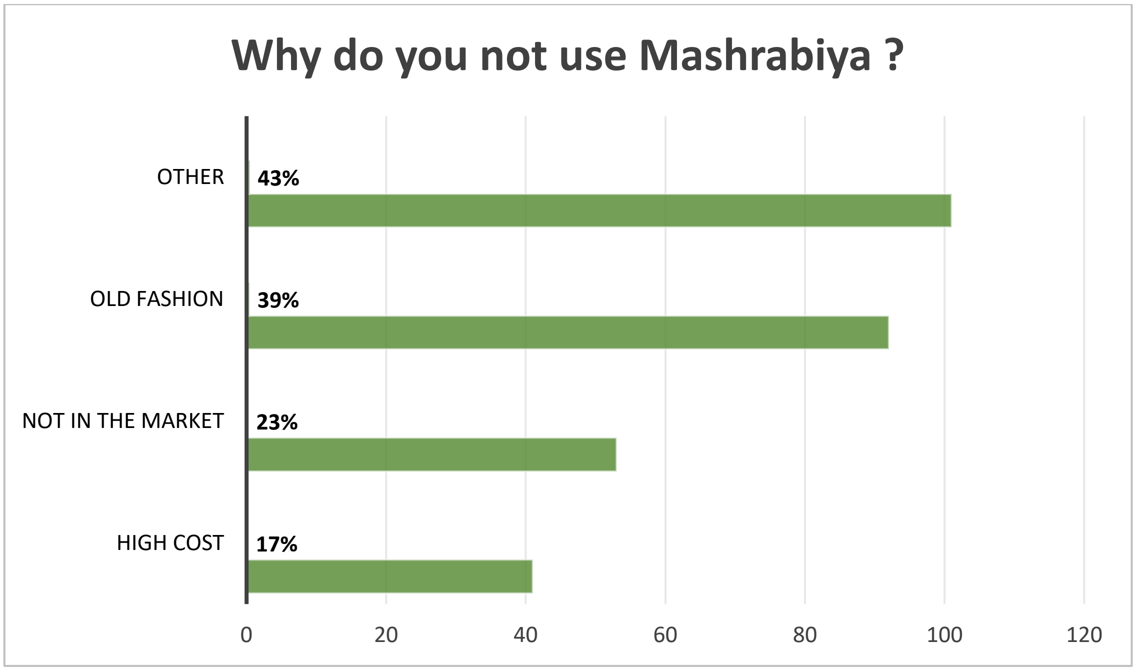


Figure 5- 9 Reasons not using Mashrabiya.

The bar graph shows the reasons provided for not using mashrabiya for the residents which are based on the residents' responses from the pilot survey. According to the results 39% stated the design as a reason for not using mashrabiya while 23% highlighted that it is not available in the market and the final 17 % claimed that it is expensive. It should be noted that around 43% selected neither of the choices from the list provided.

- **Do you have any suggestions for future mashrabiya?**

Table 5-7 Responses regarding future use of mashrabiya

No response	Responses regarding future use of mashrabiya							
	Material	Design	Coast	Aesthetic	Energy consumption	Do not use	Reinstate	Use as original
206	18	26	15	5	6	4	8	2

Table 5- 8 Suggestions for future mashrabiya

No response	Responses regarding future use of mashrabiya
206	1. It is best to leave it as it is. 2. I hope *mashrabiya* are reinstated with new designs but a reasonable price. 3. *Mashrabiya* should be modified however price considered. 4. We hope *mashrabiya* would be ideal for reducing energy consumption. 5. I am not thinking about it now but would be in the future. 6. The price needs to be affordable. 7. Use aluminium instead of wood. 8. *Mashrabiya* should be mandatory in order to save energy. 9. Material should be of good quality, not corrosive, heat responsive, water resistant. 10. Maybe iron or glass material would be suitable. 11. *Mashrabiya* is not suitable for this developed society.

12. Should be easy to process and adaptable to the environment.
13. Should be cheap but of good quality.
14. Should be modern style
15. Should be used as a means of reducing electricity bill.
16. We hope *mashrabiya* design should be kept traditional and used for its functions.
17. What are *mashrabiya*?
18. *Mashrabiya* should be made in different colours and modern materials.
19. *Mashrabiya* should be adapted to meet affordability and modern styles for people.
20. The price should be affordable as they also help to reduce energy consumption.
21. *Mashrabiya* should be redesigned especially the shape and style.
22. Electrical design of *mashrabiya* should be considered particularly as an electrical shutter.
23. A new modernised design should be introduced.
24. *Mashrabiya* should be sound resistant, with good view so people can see clearly through it.
25. *Mashrabiya* should be used as an air condition.
26. A different material to wood should be used.
27. *Mashrabiya* should be designed from a type of material which does not absorb heat and is humidity resistant.
28. While *mashrabiya* should be designed in different colours it should also be of good quality and made of aluminium
29. It should be used as a decorative architectural element.

30. *Mashrabiya* should be made available in the market at an affordable price and easy to clean.
31. The design should be modern and affordable.
32. *Mashrabiya* should be more sophisticated flexible to use and also fit the modern style increasing its functionality effectiveness while maintaining its elegance, originality, spirit, and beauty.
33. *Mashrabiya* should be electrical and move with time.
34. It should be designed using cheap and different material which is easy to maintain. Also, the shape needs to be improved.
35. The cost of *mashrabiya* should be reduced.
36. *Mashrabiya* should suit modern style, more simplified but still beautiful.
37. I do not care, not interested even if it is beautiful.
38. *Mashrabiya* should be made of material that is suitable for the climate and cheap.
39. Do not know what *mashrabiya* are.
40. *Mashrabiya* should be designed according to the style of the customer.
41. It should be affordable and modern.
42. I do not recommend the use of *mashrabiya* glass is modern.
43. Find the alternative to *mashrabiya* so that it is cheap but still has the same functions.
44. Design should be colourful and modern.
45. *Mashrabiya* should be made of fibre glass and also modernised.
46. Should be low in price.
47. People used *mashrabiya* because houses were close together.

48. Do not have any background about *mashrabiya* and carpentry.
49. I do not like the fact it restricts light.
50. *Mashrabiya* should have large holes for ventilation.
51. I hope *mashrabiya* comes back.
52. *Mashrabiya* should be included within the municipality system.
53. *Mashrabiya* needs regular maintenance.
54. If *mashrabiya* prove to be efficient in reducing energy consumption, I will use them.
55. *Mashrabiya* is not suitable for modern architecture buildings

The table (5.8) shows responses of residents and individual comments for a reconstruction of the *mashrabiya* to suit the modern world. Most of the responses indicate the fact that *mashrabiya* should be reinstated though at an affordable price and with modern designs. There is also hope that *mashrabiya* could be a solution to reducing energy consumption. In addition, the respondents showed considerable concern about the type of material that could be used for *mashrabiya* as well as utilisation of all its function in its use. Additionally, aspirations of some respondents reveal that as a decorative feature, *mashrabiya* would be ideal.

The results on the question about mashrabiya indicate that even though the majority of residents have the knowledge of mashrabiya and its functions, they do not use it. There are reasons for not using mashrabiya including the design, material, and the fact that its costly and not in the market. On the other hand, about 55 of the residents commented on the future mashrabiya if this was to be re-instated, these reasons include similar to those for not using mashrabiya as well as modernising it to suit contemporary style buildings.

5.2.7 On-line questionnaire summary

From the results above, it can be concluded that the residents are dissatisfied with the cost of electricity bill. It is interesting to note that 75% of the results show that residents have privacy while 100 % of the residents use window treatment which indicates lack of privacy. The results show that the majority of residents have the knowledge of mashrabiya including its functions and would want mashrabiya to be re-instated however, with simple design, change of material and manufactured in different colours, good quality but affordable.

5.3 Specialist's Interviews

Table (5-9) shows a summary of the number of specialists from four government organisations who participated in the questions related to energy consumption. These people were interviewed using semi-structured interviews, although there were instances where respondents digressed and added extra information on certain topics. According to the diagram, the Saudi Electricity Company (SEC) released two specialists in electrical engineering managing load and planning for the Saudi Electricity Company. The main purpose of this company is to implement government policies by ensuring residents are supplied with not only cost-efficient electricity, but the Department also prioritises reliability and safety of equipment.

Two of the participants were from Jeddah Municipality (JM), one of whom is involved with directing the planning and development of strategic projects whilst the other is the Head of Residential Projects and Building Permits Department.

The other three interviewees are from the Saudi Energy Efficiency Centre (SEEC) and include a Director in Management of Energy Efficiency Specifications, Head of the Building Team of the Saudi Energy Efficiency Centre, and Experts in Solar Energy Conservation.

It is assumed that this organisation would have re-enforced the insulation in buildings based on the SEEC standards according to SEC (2010), where the Saudi government decreed that all buildings should be insulated in an attempt to reduce energy consumption generally.

The diagram below shows the organisations and representatives from the organisations as well as their job descriptions and responses related to identity, privacy and *mashrabiya*. In diagram 3, the interviewees participated in the areas mentioned above, two of whom were from Jeddah Municipality's (JM) Directing Planning and Development of Strategic Projects department, as well as the head of Residential Projects Building Permits Department. The Saudi Commission for Tourism and National Heritage (SCTNH) released one specialist, who is the Director of Historical Jeddah Office.

Table 5- 9 Aspects Investigated Through Interviews with The Specialists in 4 Government Organisations in Saudi Arabia (Source: Alghamdi 2019)

Government Organisation	Abbreviation & Location	Participants No & position	Years of Experience	Research Method	Aspects investigated
Saudi Energy Efficiency Centre	SEEC A Riyadh	1. Detector in Management of Energy Efficiency Specifications	20	Semi structured Interview questions	• Energy Consumption • *Mashrabiya*
		2. Head of building team of Saudi Energy Efficiency Centre	6		
		3. Expert in solar energy conservation	36		
Saudi Electricity Company	SEC Jeddah	1- Specialists in electrical engineering	11		
		1. Managing load and planning	13		
Jeddah Municipality	JM Jeddah	1- Planning and development of strategic projects department director	12		• Energy Consumption • *Mashrabiya* • Architectural Identity • - *Mashrabiya*
		2- Head of residential projects building permits department	25		
Saudi Commission for Tourism and National Heritage	SCHT Jeddah	1- Director of Historical Jeddah Office	4		• Architectural Identity • - *Mashrabiya*

5.3.1 Energy Consumption

- ***Are you satisfied with the level of energy reduction in insulated residential buildings? Why?***

Table 5- 10 Architect's responses of satisfaction with energy reduction in insulated residential buildings.

ORGANISATION	INTERVIEWEE 1	INTERVIEWEE2	INTERVIEWEE 3
Saudi Electricity Centre (SEC)	No	No	
Jeddah Municipality (JM)	Not sure	No	
Saudi Energy Efficiency Centre (SEEC)	Yes because of the percentage of reduction recorded so far	Yes, compared to the proposed plan	Yes

The table (5-10) is a representation of the responses to the question of whether the organisations are satisfied with the effort made towards the reduction of energy consumption in insulated residential buildings, where three of the organisations (Saudi Electricity Company (SEC), Saudi Energy Efficiency Centre (SEEC) and Jeddah Municipality (JM)) participated in the interview. From this, it is obvious that the Saudi Energy Efficiency Centre agrees of the situation, as shown by all with a positive response related to their statistics and proposed plan. By contrast, all the Saudi Electricity Company interviewees express their strong dissatisfaction on this issue. In addition, Jeddah Municipality are also dissatisfied with the level of energy reduction, as shown by one negative response as well as uncertainty on the other.

- ***Reasons on the responses regarding the level of energy reduction in insulated residential buildings.***

Table 5- 11 Reasons for the changes in energy reduction in insulated residential buildings.

ORGANISATION	INTERVIEWEE 1	INTERVIEWEE2	INTERVIEWEE 3
Saudi Electricity Centre (SEC)	No, that is why there is an increase in the tariffs	No, there is no rationalisation of the consumption of energy in residential buildings.	
Jeddah Municipality (JM)	Not sure, however if you ask SEC more information may be given	No, not at all	
Saudi Energy Efficiency Centre (SEEC)	Yes, for now but we are working more towards reducing energy usage	Yes, for now but we are looking into reducing [usage] more through research	Yes, for the time being as we are still investigating

The table (5-11) above indicates the reasons for, or additional information to, the responses provided for the previous question. As indicated above, the Saudi Electricity Company (SEC) respondents express their dissatisfaction with the effort towards energy reduction, supporting the facts of the recently introduced increase in energy consumption tariffs. They further state that there is no justification for the current consumption of energy in residential buildings. According to the Energy Efficiency Centre, the energy consumption situation is under control, although much still needs to be done through research. As for Jeddah Municipality, one of the interviewees referenced the Saudi Electricity Company (SEC) for further inquiry while the other respondent expressed dissatisfaction with current levels of energy consumption.

- ***Rate each of the following operational systems in terms of the contribution to energy consumption in residential buildings***

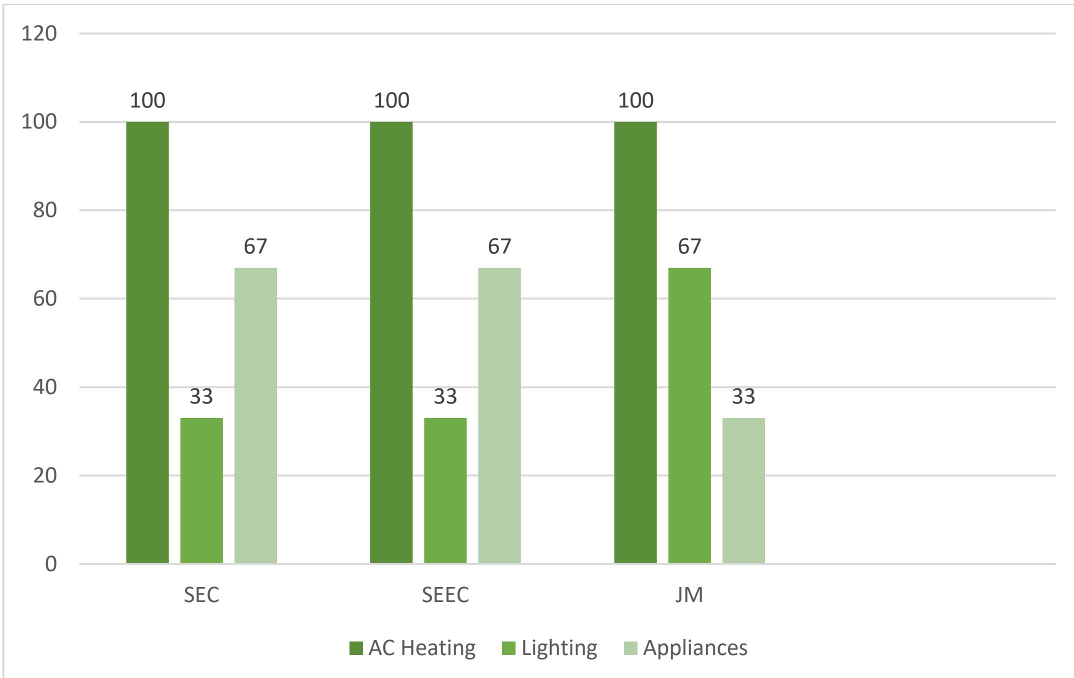


Figure 5- 10 Operational systems in terms of the contribution to energy consumption in residential buildings

Figure (5-10) show how Saudi Electricity Company, Jeddah Municipality and Saudi Energy Efficiency Centre rated the operational systems in terms of how they contribute to the increase in energy consumption. It is obvious here that all three organisations agree that air conditioning is the largest contributor to the increase in energy consumption while the lowest is the use of lighting. JM interviewees were exceptional in that they rated the appliances as the lowest with lighting being the second highest which is different from SEC and SEEC recording appliances as the second highest.

- **Responses *to rating the type of building envelope that contributes to the increase in energy consumption.***

Table 5- 12 Building envelope that contributes to the increase in energy consumption.

ORGANISATION	INTERVIEWEE 1	INTERVIEWEE2	INTERVIEWEE 3
SEC	Depends on the orientation of the building	Depends on the orientation of the building	
JM	All as a group	Location and the size matter	
SEEC	Important factors such as orientation Plan of the building Insulation construction materials Quality of appliances	Roof is the highest contributor followed by exterior walls then windows and doors	Roof and exterior wall

The table (5-12) is a summary of the responses as to which of the building envelopes among the roof, exterior walls, doors, and windows contribute more to the observed increase in energy consumption. It should be noted that the responses were allocated to the interviewees for rating. According to the responses from Jeddah Municipality and Saudi Electricity Company, orientation seems to be an important determinant factor for energy usage in conjunction with the list provided above such that if any of the element of building envelop is exposed to the sun for longer periods then it becomes a contributory factor to energy consumption and vice versa. However, two of the respondents from the Saudi Energy Efficiency Centre rated the roof as the highest contributor to the increase in energy consumption, followed by the exterior walls, windows, and finally doors. The third respondent emphasised the orientation of the building, thermal insulation, and construction materials as the greatest contributors to the increase in energy usage, including the quality of appliances.

5.3.2 Architectural Identity

- ***In your opinion, do the contemporary residential buildings reflect the identity of Jeddah's architecture (Hejazi Architecture)?***

Table 5- 13 Hejazi Architecture Identity

ORGANISATION	INTERVIEWEE 1	INTERVIEWEE2	INTERVIEWEE 3
SEC	Totally disagree	Totally disagree	
JM	Totally disagree	Totally disagree	
SCHT	Totally disagree		

Table (5-13) is an indication of the responses from SEC, JM and SCHT as to whether Hejazi architectural identity is reflected in Jeddah's contemporary residential architecture. All three organisations unanimously state that there is no Hejazi architectural identity in Jeddah's contemporary residential architecture. The responses differ in that JM believes in adapting traditional style while SCHT are of the opinion of maintaining traditional architecture.

5.3.3 Mashrabiya

5.3.3.1 General Information about Mashrabiya

- **Do you know what *mashrabiya* are?**

In relation to whether the specialists know mashrabiya, all the responses from the four government organisation interviewees expressed the knowledge of mashrabiya.

- **What are the main functions of *mashrabiya*?**

On the question of whether respondents had any knowledge on the functions of *mashrabiya*, all four government organisations claim to know at least some of these functions, such as privacy, natural ventilation, and lighting and cooling the interior though not necessarily all of them. On the other hand, the Saudi Commission for Tourism and National Heritage have a full understanding of *mashrabiya* and their functions.

- **Do you think *mashrabiya* should be reinstated in the new residential buildings in Jeddah?**

The responses from two government organisation, Jeddah Municipality and Saudi Commission for Tourism and National Heritage regarding the possibility of reinstating *mashrabiya* in new buildings. The responses from Jeddah Municipality showed two different opinions as one of them agreed that *mashrabiya* should be reinstated while the other was not sure if this would be possible. On the other hand, the interviewee from the Saudi Commission for Tourism and National Heritage was in total agreement with the idea of reinstating *mashrabiya* as it is with all its function in new residential buildings.

5.3.3.2 Energy Consumption with Mashrabiya

- **Do you think *mashrabiya* would reduce energy consumption in insulated buildings in Jeddah?**

The responses summarise the opinions regarding whether mashrabiya would reduce energy if re-instated in contemporary residential buildings from three government organisations including the Saudi Electricity Company (SEC), Jeddah Municipality (JM) as well as the Saudi Energy Efficiency Centre (SEEC). SEC interviewees are unanimously unsure of whether *mashrabiya* can be used to reduce energy consumption. Yet, on the other hand, SEEC interviewees responded positively stating that ''the use of *mashrabiya* to reduce energy consumption in residential buildings as a shading device would be ideal'', while JM respondents expressed different and contrasting views, with one agreeing and the other disagreeing.

- ***What do you think would be suitable materials for improved mashrabiya?***

Table 5- 14 Suitable materials for improved mashrabiya

ORGANISATION	INTERVIEWEE 1	INTERVIEWEE2	INTERVIEWEE 3
SEC	Suitable thermal conductivity	Suitable thermal conductivity	
JM	Wood but also ask what people want	Wood is expensive. We need materials better than wood, cheap and easy to process suitable for the climate	
SEEC	Metal will not help	Do not know maybe gypsum, Palm stem, leaf	
SCHT	No adjustment keeps the original material (wood).		

The table (5-14) reflects the responses regarding suggested materials that could be used to build improved *mashrabiya*. The responses are varied, clearly showing properties which are suitable in terms of thermal conductivity, as highlighted by the Saudi Electricity Company (SEC). On the other hand, Jeddah Municipality (JM) suggested materials better than wood which would be cheap and easy to process; in addition, the respondents mentioned the involvement of users of *mashrabiya* to choose a suitable material they prefer to use for its properties. The final response from the Saudi Energy Efficiency Centre (SEEC) suggested the use of gypsum and palm leaf stem.

5.3.3.3 Mashrabiya and Architectural identity

- ***Explain how mashrabiya could be modified to enhance the identity of traditional architecture and suit the modern style.***

Table 5- 15 Modification of mashrabiya to suit modern style architecture.

ORGANISATION	INTERVIEWEE 1	INTERVIEWEE2	INTERVIEWEE 3
JM	Responsibility of the designer	Use *mashrabiya* differently not exactly as in the past, for example not on the window only	
SCHT	It is vital to understand all the functions of *mashrabiya* so that it is not used only for beauty purposes.		

The table (5-15) shows responses on the modifications that could be implemented for *mashrabiya* that could enhance traditional identity. It is clearly stated by Jeddah Municipality (JM) interviewee (1) that the use of *mashrabiya* has improved in comparison to its use as a window in the past. On the other hand, interviewee (2) claims that any adjustments in relation to modifying *mashrabiya* are the responsibility of the designer. In addition, one respondent from the Saudi Commission for Tourism and National Heritage (SCTNH) notes a preference for residents to use *mashrabiya* mainly for its functions than for artistic/aesthetic purposes.

- ***In your opinion, should the government set the regulations for residential buildings façade to reflect the identity of the city?***

in relation as to whether the government should set regulations to reinforce identity, the results from the Saudi Commission for Tourism and National Heritage (SCTNH) interviewees highlight the fact that ''Jeddah Municipality (JM) has a special committee which is responsible for the identity of the city''. On the other hand, JM responded that controlling citizens is a major issue.

- **Which government urgency is responsible for setting laws for residential building façades to reflect the identity of the city architecture?**

On the question of which government organisation is responsible for setting laws for residential buildings facades to enhance identity, the results from SCHT indicate that because of the problems Jeddah Municipality as an organisation was experiencing, it created a committee to focus on the identity of the city. However, JM highlighted responsibility in setting laws although also claimed some difficulties in controlling people as far as construction standards were considered.

- ***Which architectural element reflects Hejazi architecture?***

According to the results on the question of which architectural element reflet Hejazi architecture all the interviewees from JM and SCHT emphasised that Mashrabiya (Roshan) are identified as the most significant architectural element reflecting Hejazi architecture.

- **Will the use of mashrabiya enhance the identity of Hejazi architecture in Jeddah?**

The respondent from the SCTNH emphasised that *mashrabiya* can enhance identity if it is used with all its functions in addition to its beauty. Moreover, the interviewee stated that there is more hidden meaning in identity than just beauty. On the other hand, the respondents from JM stated that Mashrabiya should be symbolic to reflect (Hejazi) traditional architecture.

- **What do you think should be done to reflect the heritage architectural identity in contemporary buildings?**

When asked what would reflect the heritage architectural identity in contemporary residential buildings, the interviewees from JM stated that if mashrabiya was used in many ways instead of using it as a window that would be ideal to reflect traditional architectural identity. In contrast, SCHT mentioned architectural identity limitations if mashrabiya was used for aesthetic purposes disregarding its functions.

5.3.4 Specialists' Interview summary

The results from the specialist interviews show unanimous agreement on the issue of the increase in energy consumption. While JM and SEC express dissatisfaction on the level of reduction to date, SEEC claims satisfaction since it is the leading organisation with the project at hand aiming to reduce energy consumption. In relation to the operation system and structural elements that contribute to the increase of energy consumption, all the interviewees agree that AC is the highest contributor to energy consumption while on the building envelope orientation determines which of the structural elements contributes to high levels of energy. On the question related to identity and mashrabiya, the responses from the specialist interviews confirm that while Jeddah has lost its identity this could potentially be restored by mashrabiya which is recognised as the most significant architectural element in Hejazi architecture which not only provides architectural identity but also enhances resident's privacy.

5.4 Albasateen District Residents Interviews

The Albasateen District interviews comprised of 48 residents who owned and built the villas. The researcher used semi-structured questionnaires aimed at the thread of the research including energy consumption, privacy, and identity as well as mashrabiya. The interviews were considered after the discovery on the lack of detail in some of the questions hence the choice of interviews to complement the online questionnaire and provide further details for some of the responses. Purpose for choosing Albasateen district. See section 4.7.3 site selection.

5.4.1 Purpose for choosing Albasateen District

Albasateen District fig (5-11) was chosen on the three reasons including the fact that it's a new district was constructed under government regulations requiring the use of thermal insulation. Secondly the majority of buildings are mainly villas. Finally, it shares the same location and climatic zone with King Abdul-Aziz International airport which is also recognised in design builder.

Figure 5- 11 Albasateen district location in Jeddah (Source: Google Maps)

5.4.2 General Information about Households

The section below represents the data collected from Albasateen District residents regarding gender, number of occupants, age, level of education, and employment status.

- Gender of occupants
- Age of occupants
- Size of the family
- Level of education
- Employment status

Among the 48 residents the results show that 71% of the participants are females and 29% males with ages between 30 to 70 divided into four groups with ranges of 30-40, 41-50, 51-60 and 61 to 70. The highest figure is for the ages between 41-50 at 42%, whereas the lowest percentage is for 61-70-year-olds at 6%. The second highest percentage is for the 30-40 group at 29%, while the last group for the 51-60 age group is 23%. The sizes of the families for each villa are divided into four categories between 1-3 and 4-6 as well as 7-9 and 10 and above. The figures are based on the sample from pilot survey.

Table 5- 16 Size of the family

NO of Family.	1 - 3	4 - 6	7 - 9	10 - more	Total
	8	23	14	3	48
	16.6%	47.9%	29.2%	6.3%	100%

The results table (5-16) clearly indicate that the number of occupants between 4 and 6 is the highest, with a percentage of 48, while those with more than 10 people is the lowest, with only 6%. However, the number of people with only 17% and 29% is registered for the occupants between 1 to 3 and for 7 to 9 respectively. The level of education for the participants varied from high school to Doctoral level. According to the results the majority totalling 54%, studied up to the bachelor's level, while the minority who attained a doctorate totalled only 6%. The interviewees with high school qualifications and master's degrees were almost the identical at around 21 and 19%, respectively.

In relation to the employment status of the residents, the highest score of 56% represents those in employment while the second highest is 31%, who are unemployed. Finally, the proportion of the retired is 13%.

5.4.3 Building Information

The section below comprises a summary of the building information provided by the Albasateen residents during the interview. The areas of discussion include information about the building such as the type, date of build, area of the land, and number of floors and facades.

- Type of home
- Date of construction
- Area of land
- Number of floors
- Number of façades

Even though Albasateen is mostly populated with villas there are, however, some apartments in the area. Since the research focussed on villas only, 48 villas were chosen, represented by 100%. The date of construction was pivotal in the research as it showed implementation of government regulation, so the piece of information collected from the residents was that of the year the villas were built, ranging from 2000 to 2017 and grouped into three 5-year periods. The most popular period was 2006 to 2011, at 56%, and was the highest, while 2012 to 2017 was the lowest at 8%. Lastly, 2000 to 2005 was the second highest with a figure of 35%. The results indicate that the district is new.

Another aspect of the inquiry about the building information included the provision of measurements of the area of land by residents, which was divided into three ranges between 300 to above 901 square meters. According to the results given, the two groups with areas of 300 to 600 and 601 to 900 m^2 recorded the same percentage of 42%, totalling up to 84% for both and were the highest. In contrast, the responses for the range above 901 m^2 was the lowest at only 16%. The results show that the typical villa in Albasateen district is between 300 and 900$m^{2.}$ It is clear that all the villas in Albasateen district follow Jeddah municipality regulation of two floors and an annex. The results from Albasateen district show that all the villas 100% have three floors (two floors and an annex). On the investigations regarding the number of facades, the majority of villas, 48%, have one façade and is the highest proportion, while villas with three façades are the least common at a proportion of 10%. Finally, villas with two façades are the second highest at 42%.

5.4.4 Construction Details

The construction section has four parts including the type of construction material, thermal insulation, outside finishing and glazing.

- Type of construction material
- Type of thermal insulation
- Type of Outer finishing
- Type of glazing

Table 5- 17 Type of construction material

Type of construction material	Red block	Siporex	Volcanic block	Two walls and insulator	Total
	31	10	4	3	48
	64.5%	20.8%	8.3%	6.2%	100%

The results table (5-17) show that the most common type of construction used by the residents is the red block with a percentage of 31In regards to the use of thermal insulation, it is clear that 100% of the residents use thermal insulation with 80% using polystyrene and 20% Siporex block.

Table 5- 18 Type of Outer finishing

Type of Outer finishing	Plastic Paints	Cement Paints	Marble	Stone	Total
	18	20	6	4	48
	37.7%	41.6%	12.5%	8.3%	100%

In relation to the outer finishing, table (5-18) shows the majority of residents use both plastic and cement paints, it should be noted that marble and stone can also be used as outer finishing for the building for protection from solar gain. It is clear that all the respondents use double glazed windows in their villas.

5.4.5 Cooling System Information

The investigation on the cooling system focused mainly on the types and set point of the air conditioning systems (AC).

- Type of AC
- AC Set point

The results from the interviews clearly demonstrated a wider use of various types of air conditioning (AC) such as window, split and central cooling system. The majority of residents prefer a central type of AC, at 77% which is the highest. However, the split and window type are close with percentages of 25% and 19%, respectively, although the window is the lowest.

Table 5- 19 AC Set point

AC Set point ^{0}C	**16 - 18**	**19 - 21**	**22 - 24**	**48**
	18	25	5	48
	37.5%	52.1%	10.4%	100%

On the question of air conditioning set point, table (5-19) shows that most of the residents about 90% prefer a set point between 16 ^{0}C to 21 ^{0}C while SEEC recommends 23^{0}C to 25 ^{0}C as the suitable interior indoor environmental quality' . According to literature review AC consumes 70% of energy in residential buildings. see section 2.2.3 literature review.

- Table of living room results from observation.

Table 5- 20 Observation table

Tick box table			
A.C Set point	16 - 22 ^{0}C		
Living room area	30 -80 m^2		
Height of Ceiling	2.75 – 3 m		
Floor finishing	Marble, porcelain, wooden floor, ceramic, carpet,		
Wall finishing and colour	Plaster, wallpaper, stone, paint,		
Number of sofas	3-10 pieces		
Number of windows and size	1-5 windows, 3 m^2 -12 m^2		
Type of glass	Double glazing		
Window shading	✓ Curtain	✓ Black out	✓ Shutter
Type of light	✓ Natural	✓ Artificial	
Type of artificial light	✓ Florescent	✓ Halogen	LED
Type of resident's clothes	cotton		
Resident's comfort	Yes		

The table (5-20) above shows the list of information and figures of the summary of the areas of all the villas which were observed during the interviews with the 48 Albasateen residents. According to the observations, the results show the range of set points for the AC in the living room between 16-22^{o}C. The sizes of the living rooms also varied from 30-80 m^2. The height of the ceiling for each living room also ranged between 2.75 - 3 m. The residents used marble, porcelain, and ceramic for the flooring as well as wood and carpet. The wall finishing included plaster with wallpaper and plastered painted wall as well as stone finishing. The number of sofas in the living room ranged from 3 _10 while the sizes were between medium and large. The living room had 1- 5 double glazed windows with a total area of glass ranging from 3 – 12 m^2 and various shading devices such as curtains, blackouts, and shutters. The lighting used in the living room included both natural and artificial sources, such as florescent, halogen and LED. The residents wore light to heavy cotton clothing as observed and claimed to be comfortable.

5.4.6 Energy Consumption

- What is the annual cost of your electricity bill?
- Are you satisfied with the cost of the electricity bill?
- When do you use the air conditioning system the most?

Table 5- 21 Annual Electricity bill

Annual Electricity bill	5000 - 10000	10001-15000	15001-20000	20001-25000	25001-30000	More than30001
Number	20	19	1	3	2	3
Percentage	42%	40%	2%	6%	4%	6%

The information on the table (5-21) regarding the annual bill shows the first two categories between 5000 to 15 000 represented by 82% will experience an increase in tariffs of more than 60% compared to the range between 15001 and above which would be 40% a difference of 20% on both categories.

The highest percentage reflects the number of residents who are dissatisfied about their annual cost of electricity, at 83%, with only 17% of respondents claiming to be satisfied with the cost of their electricity. If the 83% of the residents were dissatisfied with their tariffs before the increase it is highly likely that the impact will even be greater in the new tariff system.

According to the results, 100% of the residents use the AC in summer, autumn, and spring, whilst 79% use it in winter. In contrast, 21% claim not to use their AC during winter. The results show the highest number of 79% using AC in winter which shows the possibility of the use of mashrabiya during this season.

5.4.7 Architectural Identity

- Significant elements of Hijazi architecture
- Reflection of contemporary residential building in Jeddah to Hijazi architecture
- Jeddah Lost its Identity
- Reasons for the loss of Hijazi architectural identity in Jeddah.

Identity can also be interconnected to cultural aspects. While Jeddah is in the Hejaz region, it is also the largest city to reflect Hejazi architecture with significant architectural elements such as *mashrabiya*. When residents were asked about the significant elements of Hejazi architecture m*ashrabiya* were most frequently mentioned as significant architectural element, at 92%, while building construction and design recorded 8.3%. On the question of whether contemporary residential buildings reflect the identity of Hejazi architecture, 90% of the interviewees stated that the residential buildings do not resemble Hejazi architecture, while the remainder said they did.

The responses from the residents on why Hijazi architecture is not reflected in modern residential buildings in Jeddah, lies on the factors listed below fig (5-12) including globalisation, modernism, western effect, different construction materials and free choice of design with figures of 37.5, 29.2, 10.4 and 6,3% respectively. When asked on why Jeddah lost its Hijazi identity, residents mentioned Western influence and modernism which are also the same factors for the reasons for the lack of Hijazi architecture in modern residential buildings. However, on the loss of identity two other factors were highlighted which include the change in construction materials and freedom in choice of design. By contrast, for the reasons for the lack of Hijazi architecture in modern residential buildings, globalisation was considered another factor.

- Reasons for the loss of Hijazi architectural identity in Jeddah.

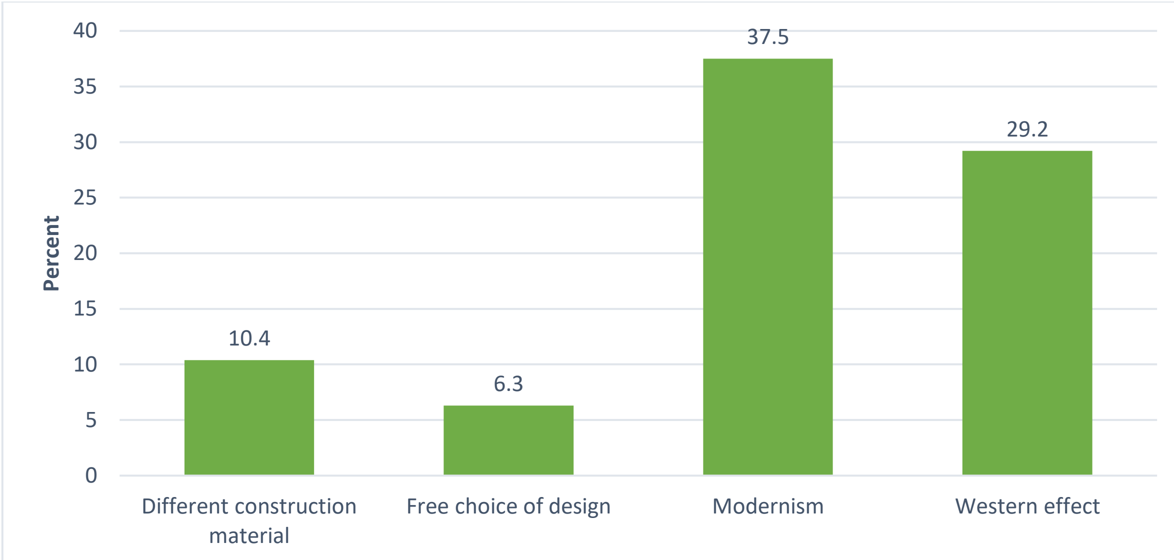


Figure 5- 12 Reasons for the loss of Hijazi architectural identity in Jeddah

5.4.8 Resident's Privacy

- Are you happy with privacy?

This section of results discusses cultural aspects such as architectural identity and privacy. Privacy can be identified as one of the core elements that affect architecture, particularly in Saudi Arabia see section 2.4.3 in literature review. On the other hand, privacy is intertwined not only with culture but also stems from the requirements of the Islamic religion. Because of the fact that privacy is linked to religion, the majority of people may not admit to lacking privacy since this reveals shameful behaviour that is considered unacceptable in society. This goes to show that privacy is a term treaded with caution in Saudi Arabia since it is intricately linked to religion on the other hand privacy is claimed to have been reduced by immigrants through buildings reflecting own cultural background. Having shown the levels of privacy another way of defining privacy drawing from the statement above (Privacy has different levels beginning from self, family, and relatives as well as female, male guests, and outsiders. Privacy increases or decreases depending on who one is exposed to).

On the question of whether residents are satisfied with the level of privacy the results indicate that 75% reported that they have privacy while only a quarter of the residents claimed not to have privacy. However, the picture below shows a variety of window treatments used by residents including shutters, curtains, blackouts, and high vents. While these window treatments are used to stop the glare from the sunshine, they are also used to increase the level of privacy.

Figure 5- 13 Use of high fence to provide privacy in villa.

The pictures taken during the interviews with Albasateen residents show 100% of the residents use some form of window treatment. This clearly indicates that there is lack of privacy. The use of shutters as reflected by a total percentage of 58, curtains at 69, trees at around 30, as well as type of glass are all evidence of the attempts to provide privacy. Additionally, residents go on to use tall fences to increase their levels of privacy.

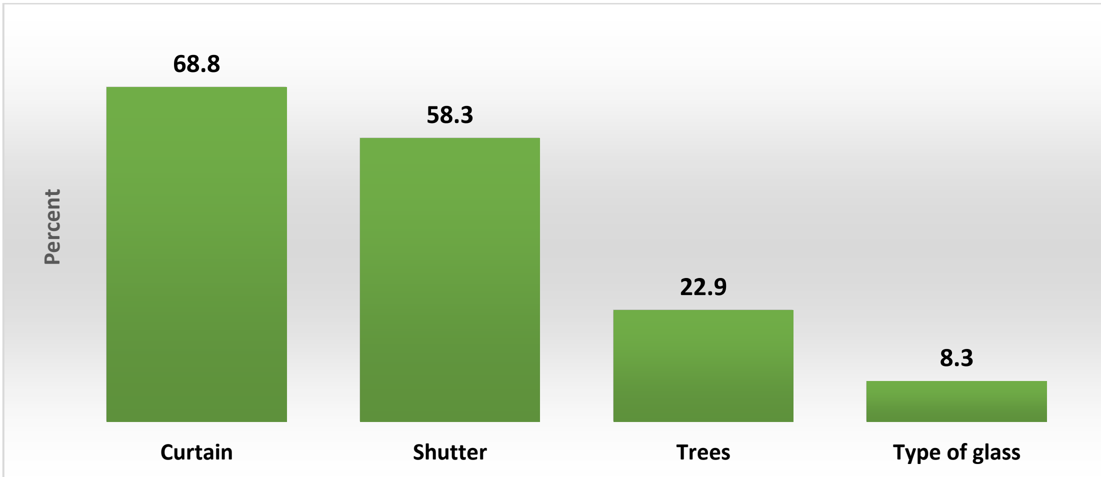
Figure 5- 14 Use of curtain and shutter to provide privacy.

Figure 5- 15 The use of both the shutter and curtain to prevent the glare.

Figure 5- 16 The use of curtains and trees to provide privacy.

Figure 5- 18 Use of high fence and shutter to provide privacy in villa.

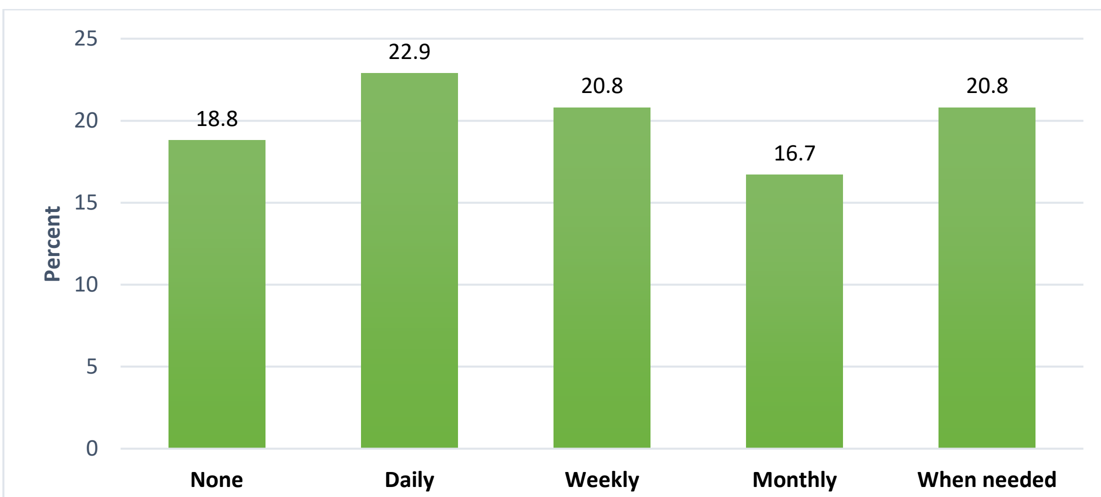
- Ways to protect of privacy.



Responses on the way to protect of privacy

Figure 5- 19 Ways of increasing levels of privacy

- Typical use of windows for ventilation

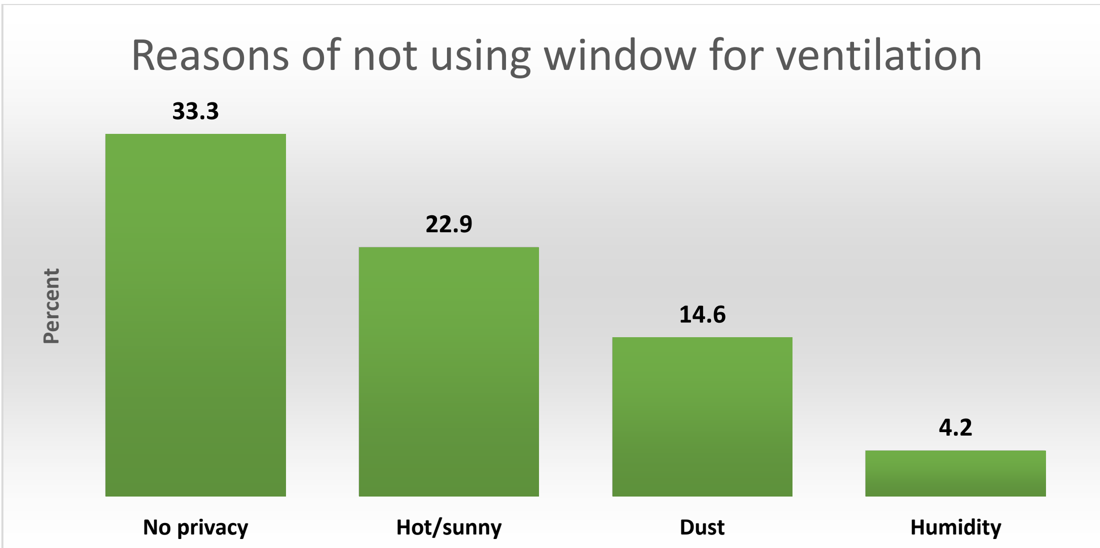


Responses on the typical usage of windows for ventilation

Figure 5- 20 Typical usage of windows for ventilation

On the question of when residents use the window for ventilation, nine residents highlighted that they never use the window for ventilation. It should be noted that the responses from the interviews reveal that only males and maid servants open windows for ventilation.

- Reasons for not using windows for ventilation



Responses on the reasons for not using windows for ventilation

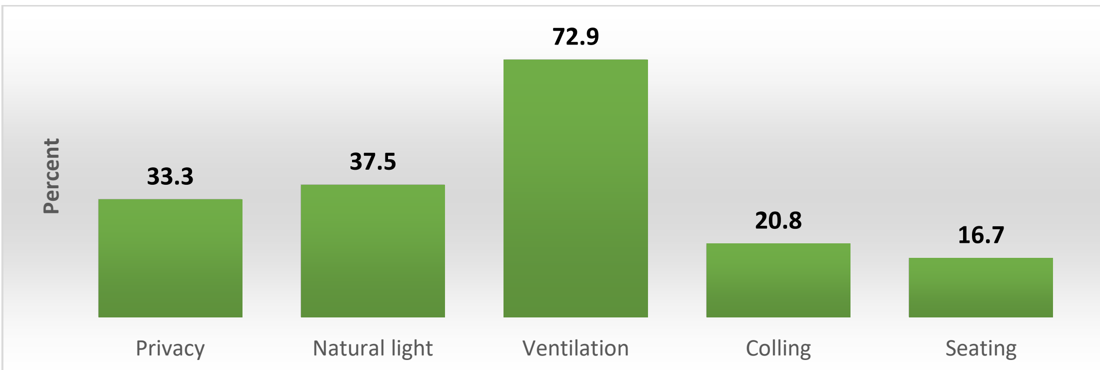
Figure 5- 21 Reasons for not using windows for ventilation.

The bar chart above show reasons why residents did not use the window for ventilation. These include lack of privacy, hot weather, dust, and humidity; according to the results, 33% claim that there is no privacy while the rest mention uncomfortable weather conditions during certain months of the year.

5.4.9 Mashrabiya

- knowledge *Mashrabiya*
- Function of *Mashrabiya*

The responses below are from a collection of questions investigating residents' knowledge about mashrabiya, whether they use it and if not provide reasons for lack of use. The questions also provided an opportunity for residents to contribute to the refurbishment of mashrabiya in the future to suit contemporary architecture. According to the interviewees on the knowledge of *mashrabiya*.it is clear that 98 % have knowledge of *mashrabiya* compared to only 2% who stated that they have no knowledge of *mashrabiya*.



Responses on the functions of mashrabiya

Figure 5- 22 Function of Mashrabiya

It should be noted that the responses provided by residents were varied but all describing the functions of mashrabiya. For example, some residents mentioned descriptive words such as 'mashrabiya brings sunlight' which can be summed up as natural lighting or 'refresh interior air' which can be natural ventilation. On the question of whether residents know the functions of *mashrabiya*, the highest percentage of the residents, a total of 73%, highlighted natural ventilation, followed by natural lighting noted by 38% of residents. The lowest percentage, about 17%, was for the use of *mashrabiya* for seating in order to relax and view the outside world. The third highest is the use of *mashrabiya* to provide privacy, at 33%. Finally, 21% of the residents identified *mashrabiya* as a cooling device.

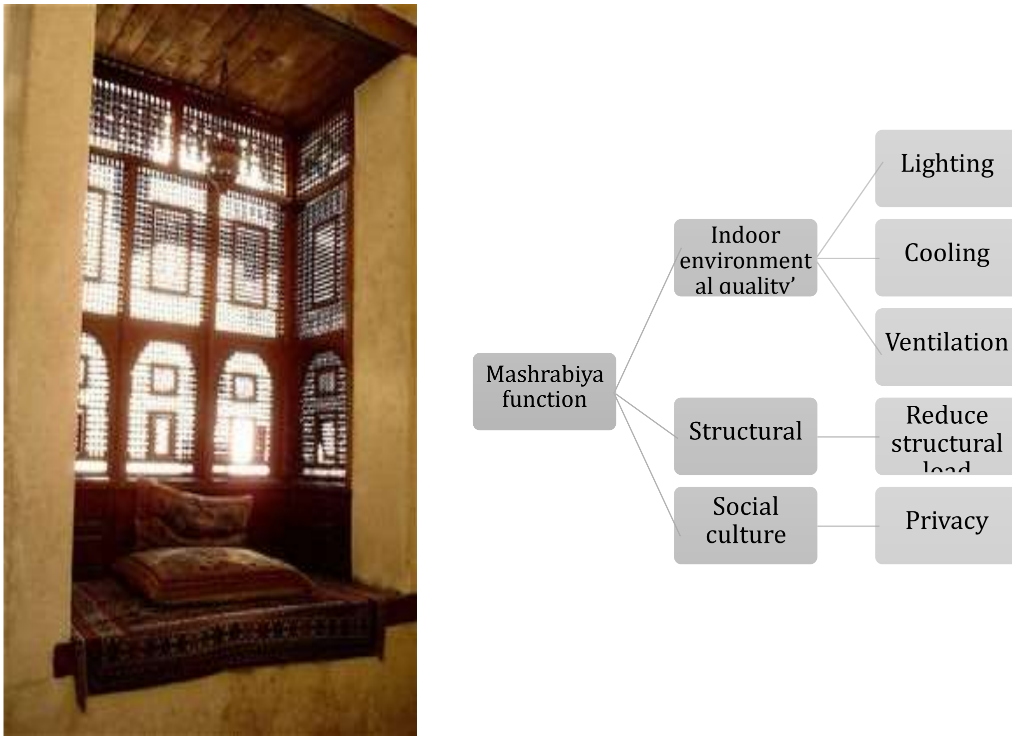
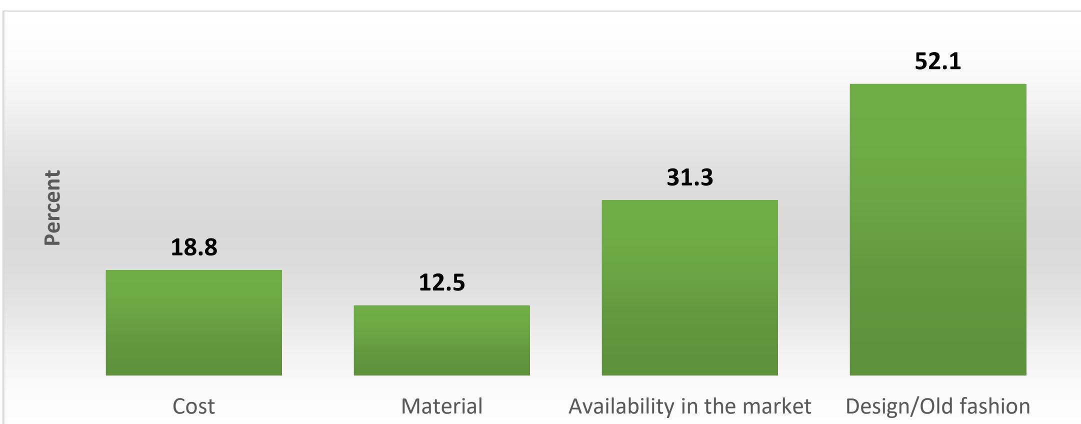


Figure 5- 23 Mashrabiya functions

- Reasons for not using *mashrabiya.*

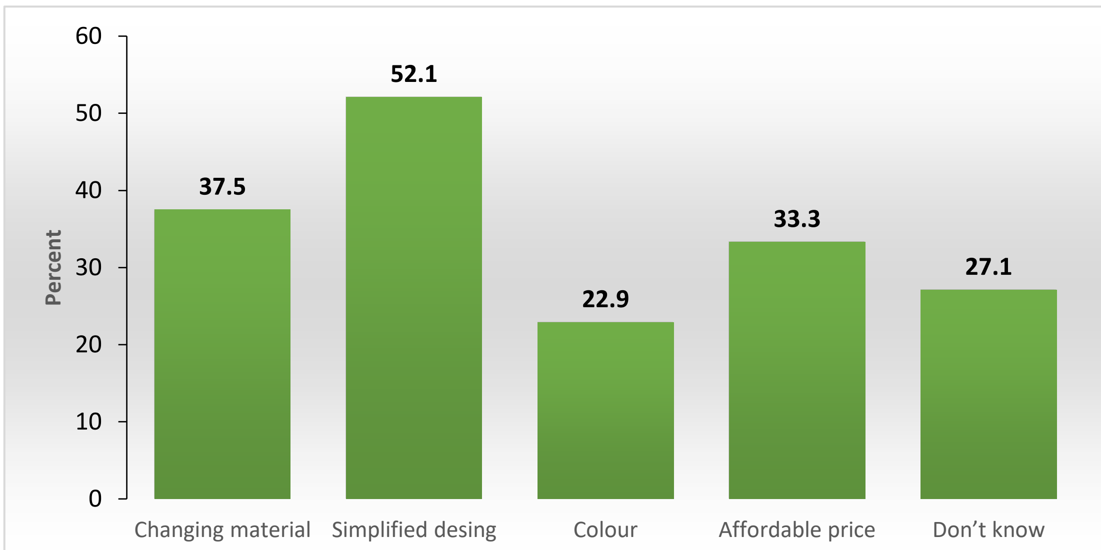


Responses on the reasons for not using *mashrabiya*

Figure 5- 24 Reasons for not using mashrabiya.

When asked why they did not use *mashrabiya*, the residents provided several reasons which were categorised into 4 groups. Some of the responses included words such as 'expensive' listed under cost others stated that they disliked wood which was highlighted as material issue. In that way 52% mentioned design, while the lowest percentage required change of material, a total of about 13%. The second highest highlighted the shortage of mashrabiya in the market which scored a percentage of around 31%. Lastly, residents stated the cost as reason for not owning *mashrabiya*, at a total of about 19%.

- Ways of improving *mashrabiya.*



Responses for residents on the ways of improving mashrabiya

Figure 5- 25 Ways of improving mashrabiya.

In response of how *mashrabiya* can be improved to suit modern society, the residents highlighted five possibilities which used different vocabulary such as 'mashrabiya should be simple' this was summed up as design while others said they 'hate wood' the response was listed under material, the majority of respondents highlighted a simplified design of traditional *mashrabiya*, at 52%, and was the highest, while the change of material was the second highest at about 38%. On the affordability of *mashrabiya*, the percentage was as close to that of change of material, being lower by only 5%. The lowest of the suggestions was the colour of *mashrabiya* which was about 23%, although 27% of the respondents were unable to provide any suggestions.

5.4. 10 Indoor environmental quality

5.4.10.1 Importance of Indoor environmental quality

Comparison of the Importance and Evaluation of the Elements of Interior Indoor environmental quality

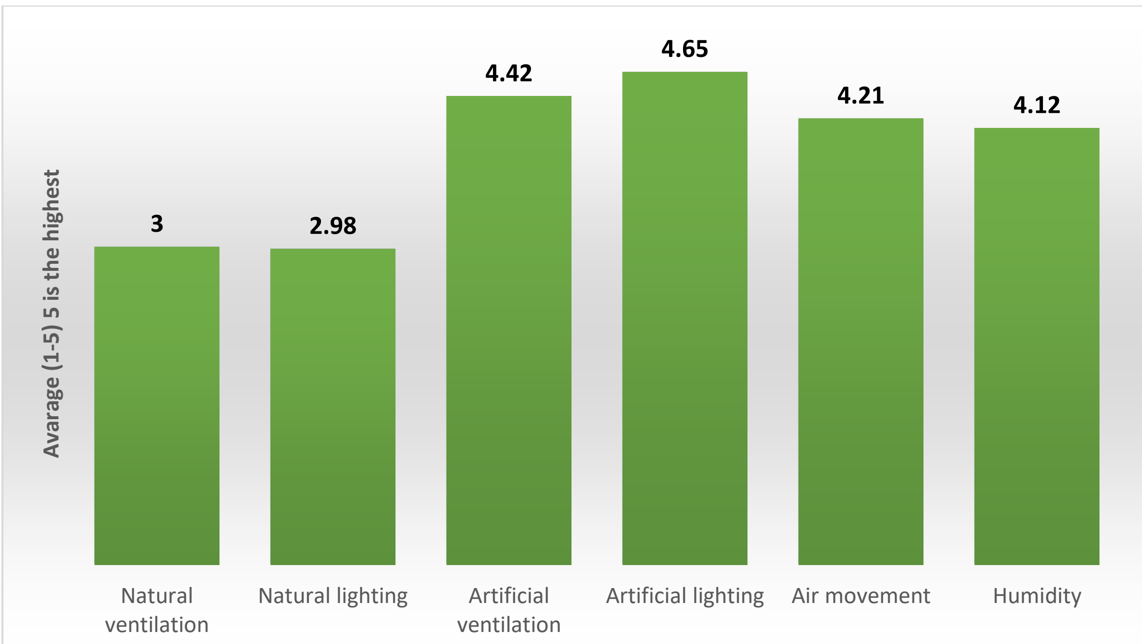
Figure (5-26) below is a representation of how residents rated factors in their homes. According to the results, natural lighting and ventilation are rated first and second with figures of 4.92 and 4.71, respectively. On the other hand, the lowest figures represent artificial lighting and ventilation at 2.98 and 3.00, respectively. Air movement and relative humidity are third and fourth position, with figures of 4.21 and 4.12, respectively. It is interesting to note that the residents acknowledged the importance of natural lighting and ventilation which can be resolved by the use of mashrabiya. This also shows how the glass window may not provide natural lighting and ventilation due to the use of window treatments.

Ratings of residents of the importance of elements for interior indoor environmental

Figure 5- 26 importance of elements for interior indoor environmental quality

5.4.10.2 Assessment of Elements of Indoor environmental quality'

Figure (5-27) below is a representation of how residents assessed and rated factors in their homes. According to the results, artificial lighting and ventilation are rated first and second with figures of 4.65 and 4.42, respectively. On the other hand, the lowest figures represent natural lighting and ventilation at 2.98 and 3.00, respectively. Air movement and relative humidity are third and fourth position, with figures of 4.21 and 4.12, respectively.



Ratings of residents on the assessment of elements for interior indoor environmental

Figure 5- 27 Assessment of elements of interior indoor environmental quality

5.4.11 Residents Interview Summary

From the results above, it can be concluded that among the operational systems the use of air condition contributes to the increase in energy consumption. Included in the operational systems is the impact the type of light has on energy usage however during observations the residents preferred halogen and florescent which consumes more energy than LED lighting. In an attempt of reducing energy consumption the construction material plays a major role. In this case all the villas in the interviews used thermal insulation and double-glazed windows. In regard to identity the results indicate that the contemporary residential buildings do not reflect Hejazi architecture and therefore Jeddah has lost its identity. According to the results it is clear that the majority of residents use window treatment indicating lack of privacy. The research seeks to highlight the potential mashrabiya could have if used in its full functions given the continuous increase in energy consumption, lack of identity and privacy as indicated by the results from the interviews.

5.5 Conclusion

This conclusion sums up the results and presents findings from the data collected through 261 responses from online questionnaire, interviews from the specialists and Albasateen residents as well as photos and measurements taken during observations. The aim of the data collected was to address the questions of continuous increase of energy consumption, the identity of the city and privacy, as well as confirm the significance of *mashrabiya* in residential buildings. The results from the specialists revealed that AC is a major operational system that contributes to energy consumption which was also indicated in the literature review in 2.2.3. In the investigation of the impact structural elements have on energy consumption, all the specialists pointed out that all the building envelopes contribute to the increase in energy consumption however, added the fact that orientation determines which building envelope is the highest contributor to the increase of energy consumption. In relation to the identity of the city of Jeddah, the specialists universally agree on the loss of architectural identity. In an attempt of solving the issue of identity, the specialists indicated that the use of mashrabiya would potentially enhance Jeddah identity since it is a significant element in Hejazi architecture. In addition, mashrabiya could potentially reduce energy consumption as a shading device.

The investigations carried out on the Albasateen residents showed that a typical villa comprises of 3 or 2 storeys and an annex with an area of 300-900m^2 occupied by 4-6 people. The results indicated that the area of the house and number of occupants contribute to the increase in energy usage as also confirmed in literature review in 2.3. The findings showed that while residents claimed to have privacy, they used window treatment to increase the level of privacy. The residents deprived themselves on natural lighting by using shutters. blackouts and curtains. However, when asked to rate what they value the most in their homes, natural lighting and ventilation was prioritised yet in evaluating the house the these were the least in the order of importance. The residents showed much knowledge on mashrabiya and its functions yet, they did not use it stating the reasons of cost, design, and material. This showed that if mashrabiya was modified the residents would be willing to use it in the future.

Having interviewed 48 residents in Albasateen District, one villa was selected on the fact that it is a typical villa which has three storeys, 4-6 number of occupants, area of land between 300-600m^2. This villa uses central type of AC and also the owner volunteered to provide all the information required for the research questions to be addressed.

CHAPTER SIX

6. Case Study Villa, Design Builder and Simulation

6.1 Introduction

This chapter provides background information about an existing villa in Saudi Arabia, in Jeddah, particularly in Albasateen District, which has been chosen as a case study. The purpose of this case study is to investigate the social cultural aspects which include residents' privacy and architectural identity as well as building energy performance in a hot climate. The villa case study will enable the researcher to investigate energy performance using design builder to simulate the existing building with and without mashrabiya. See methodology 4.2.2.1.2. The subdivisions in this chapter include six sections divided into two part in which the first part includes the purpose for choosing this villa, its location, and the villa case study information. Included in the villa case study information is the plan, villa description, household characteristics and materials of construction as well as window details. The information collected from the case study villa involved the air condition, electricity bill measurements taken as well as data from observations. The specific data that was collected during the interviews included the total electricity bill paid per year, the record of both indoor and outdoor measurements of temperature, air speed and humidity will also be highlighted. Included in that session will be information about artificial and natural lighting.

The second part in this chapter includes the inputting of data into Energy Plus software program (Design Builder) to create 3D case study villa model and simulate it with and without AC. See methodology 4.2.2.1.2.

The third part of the chapter will consider the detailed process of conducting a range of simulations and subsequent analysis of the results. The purpose of the case study for this research is to examine the impact of *mashrabiya* in villas on energy consumption through simulations run from the data collected in the field survey, chapter 5. Using the villa also enables the researcher to highlight some of the architectural elements which contribute to the increase in energy consumption. Several simulations will be run to investigate changes or impact as a result of the inclusion of the test on the existing building with *mashrabiya*. For example, what the changes in indoor temperature would be when *mashrabiya* are used with or without AC. The researcher hopes to check several aspects such as operative temperature, solar gain, and humidity as well as natural ventilation and lighting which, by the end of simulation runs, will show how the main areas of research such as reduction of energy consumption. If the results confirm that *mashrabiya* is effective in reducing energy consumption, then their adoption would also automatically solve the social issues of identity and privacy. Finally, the conclusion will summarise the whole chapter.

6.2 Purpose of Choosing the Case Study Villa

There are many reasons why this villa was selected as a case study, one of which is that the residents were welcoming and willing to share important information, such their electricity account and villa plan, relevant to the research. The respondents extended a certain willingness to provide necessary information if needed after the interview. Another factor for choosing this villa was based on several of its characteristics including the number of occupants, where a normal family in Jeddah Albasateen District is around six. In addition, this villa case study is characterised by having three storeys similar to the majority of typical villas in the area. Finally, the size including area of the land and the building as well as building construction materials and thermal insulation, also qualifies this villa as a typical home for Saudi families. Further justification for the choice of villa is the cooling system type, which is central air conditioning (AC). While the features were another reason for the choice of the villa, these also included the fact that it is not only owned but also built by the landlord and located in an ideal place, which is the city of Jeddah in Albasateen district.

6.3 Geographical Location for the Case Study Villa

The maps below show the exact location of the villa used in the case study. The investigation for the research mainly encompasses the city of Jeddah, in particular Albasateen district. Based on the requirements of the research, this district was selected for its popularity in villas which make up more than 90% of the types of accommodation in the area. Jeddah is situated on the coast of Red Sea, while Albasateen itself is north-west of Jeddah. The location of Albasateen district is in the same zone as King Abdul-Aziz International airport, hence Design Builder includes King Abdul-Aziz International airport weather data. This district covers an area of around 5.78 km^2. After interviews with residents on various aspects of the research, the researcher identified this villa as a possible case study as the owners showed a willingness to provide any useful information that might be considered essential to the research including the plan for the villa, energy bills, and any observations as per research requirements.

Maps showing the geographical location of Jeddah, Albasateen, and the specific location of the villa.

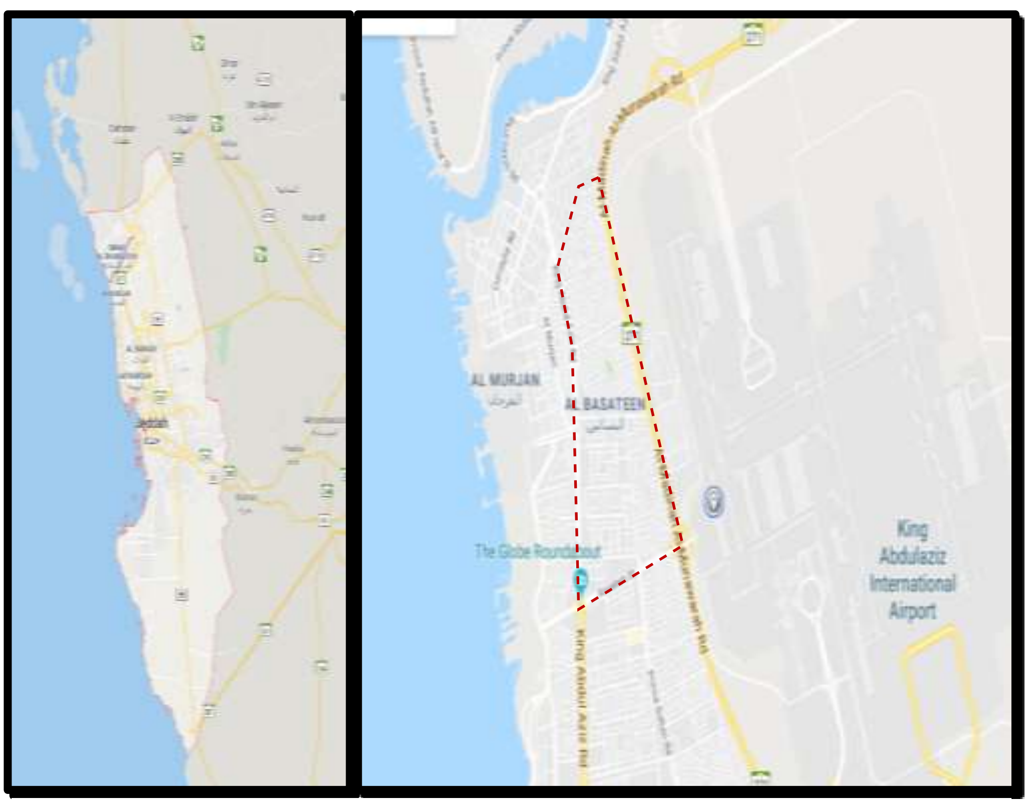


Figure 6- 1 Albasateen district location in Jeddah city

Figure 6- 2 Specific location of Albasateen district

Figure 6- 3 specific location for the chosen villa

Figure (6-3) shows that the villa is situated at the top right hand of the intersection road. The villa has a southern and western orientation.

The responses from Albasateen residents' interviews See 5.6.3 Building Information showed that the highest percentage of villas was built between 2006 and 2011, which is

56%, and that the chosen case study villa was built during this same period. In relation to the area of land, the selected villa is in the highest category with a percentage of 42%, on the other hand the number of facades lies in the second place at only 42% for the villa's two facades. The majority of the residents' villas use red block construction material which is the highest at 65%. Moreover, the thermal polystyrene insulation type also recorded was the highest at 79%, while the plaster outer finishing also had the highest score of 42%. This villa case study is a sample of many other villas in Albasateen district, though with the same characteristics.

Table 6- 1 Case study villa information

Residential building (Villa)	Description
Location	Saudi Arabia, Jeddah, Albasateen District
Design temperature	Cooling: Set point 16-22^{0}C
Shape	Cuboid
Height	9 metres
Lighting	Recessed florescent &Halogen
Occupancy schedule	4 all day and 2 half days
Ventilation	Mechanical
HVAC system	Central
Orientation	southwest

6.4 Case Study Villa Information

- ***Plan and Image of the Villa Case Study***

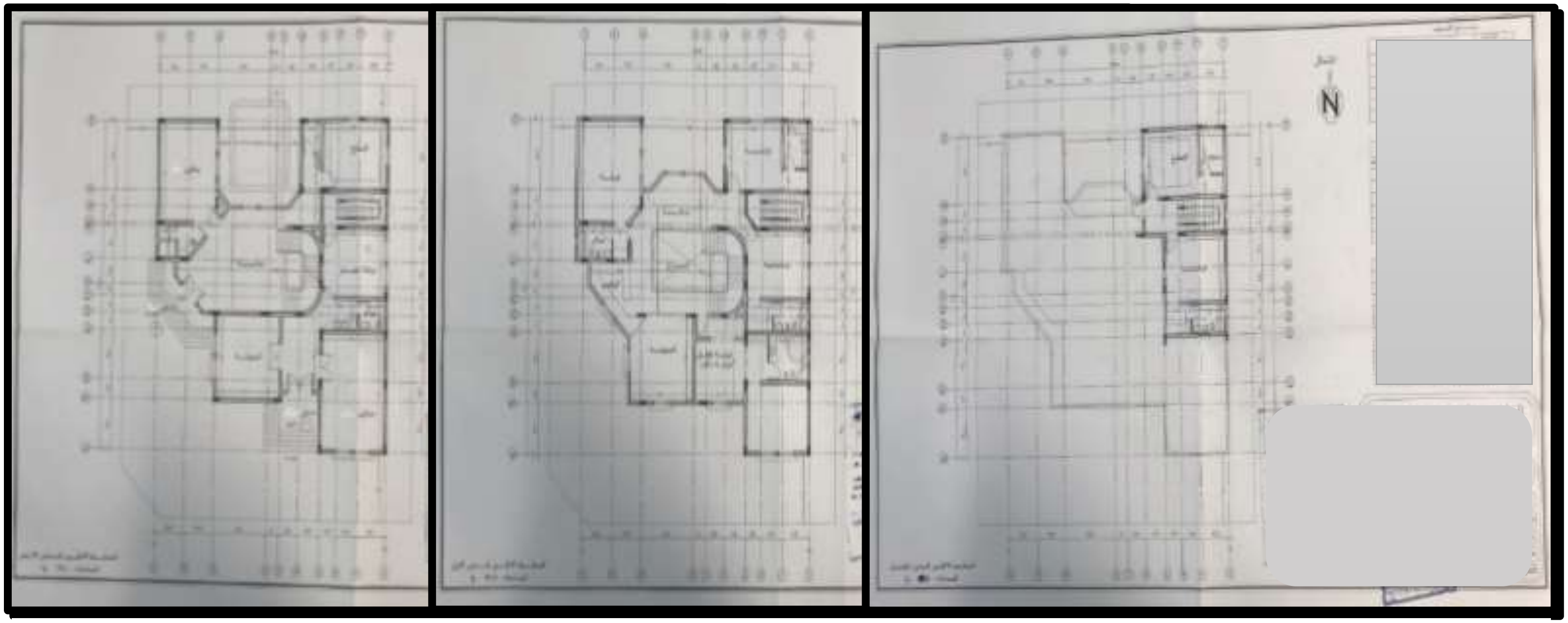


Figure 6- 4 Ground, first and second floor plan of the case study villa

Figure 6- 5 Southern and western view of case study villa

The images above are views of the villa chosen for the case study. The left-hand side view is of the south-west façade, while the right-hand side view is of the south-east facade. It is clear from the images that the villa has a wall around it to increase the level of privacy, which goes to show the extent to which privacy is valued by the occupants. While there are large and small windows which are intended to provide natural lighting and ventilation, the disadvantage is that residents rarely open windows and choose to use air conditioning (AC) instead. In an attempt to control indoor environmental quality using air conditioning and continuous use of artificial light, energy usage has increased. The continuous rise in energy consumption adds to other issues that residents identified during the interview and questionnaire data regarding Jeddah's loss of identity and lack of privacy.

- ***Description of the Villa Case Stud***

Table 6- 2 Case study villa information

Building age	Total area of plot	Built area of floors	No. of floor	Floor height	Orientation	Number of rooms/salons
14 years 2006	572 m^2	936 m^2	2 & Annex	3 m	Southwest	9

The table 6-2 above is a representation of the building information which was used as input for the simulations. Each of the areas mentioned has been scrutinised in relation to how they contribute to the increase in energy consumption with the use of *mashrabiya*. In addition, the issue of identity and privacy has been investigated and conclusions will be drawn as to whether using *mashrabiya* provides identity and privacy in this villa case study. Table 6.2 clearly indicates the year in which the building was built, also indicating that any of the buildings constructed after 2010 were insulated since they were subject to the government act which made insulation mandatory for all villas. The information also includes the total area of the plot as well as the number of floors in the building. It should be noted that among the interviewees some villas were already insulated before 2010 even before government regulations which were implemented in 2010 because of individual awareness on the impact of insulation on energy usage. (Santin, 2010) states that more energy is consumed for every additional room in a dwelling as well as the presence of a garage, a shed and a basement as these places may require indoor comfort. This implies that the larger the building or number of rooms, the higher the level of energy usage.

In addition, the table shows six occupants in the villa. (Opstelten et al., 2008) found that there is a relationship between the number of occupants and the overall decrease in residential building energy consumption; therefore, conclusions can be drawn that the number of occupants may have an impact on the levels of energy consumption. However, it should be noted that the occupancy behaviour may vary from one household to another, hence other factors should be considered. In this case, (De Dear, 2004; Lenzuni, 2008) highlight variations in the control of heating and ventilation system to suit the demands of indoor environmental quality of each household.

The table also shows the area of the villa. According to (Andersen, Shhreiker and Shukuya, 2009) socio-demographic characteristics such as household size and age of occupants have an impact on the level of energy consumption. Several authors have noted the differences in behaviour pattern in relation to age as (Liao, 2006; Chang, 2002) note that older household owners tend to consume more energy than younger property-owners. In addition, (Santin, 2010) elaborates that not only the level of education but the country of origin and income play a major role in indoor comfort preferences. (Papakostas and Statiropoulas, 1997) state that two factors that impact on energy consumption include the behaviour of occupants and technical architectural characteristics.

- ***Household characteristics***

The selection of the case study villa is significant in terms of the figures for the number of occupants, the age, and the gender of the interviewees as well as the educational status, which is reflected by 48%, 42% and 71%, respectively as a percentage of the whole group of interviewees from Albasateen district as summarised in the section 5.6.2 on Data for online questionnaire and interviews.

The interviewee is female. The number of occupants is 6 and the villa is within the highest percentage of the group of respondents. The interviewee is also aged 49 which is within the highest percentage for the age range. Regarding the level of education as well as employment status, it is interesting that the respondent is also in the highest percentage, which is the bachelor's level, however, for employment status, she is in the second highest, being unemployed. The information for this case study villa is, then, essentially a true reflection of typical Albasateen residents. This is shown by the fact that the responses in relation to the type of accommodation not only show 100% villas but describes the villas to have two floors and an annex. In addition, all the villas have double glazed windows.

- ***Construction and Envelope Materials for the Villa Case Study***

Construction materials play a major role in both energy performance and their potential effect on the environment. In choosing building materials, there is a need for sustainable materials to be considered. According to (Watkin, 2009) sustainability is defined as not only in terms of energy consumption and insulation, but it should also be viewed as more than just leaving the world in a better and richer state than we found it. The differences in energy consumption from one household to the other vary as (Nieman and Gommands, 2007) highlight the fact that it is based on quality of construction and occupancy pattern.

Table 6- 3 Case study villa construction material details

Construction type	Thermal insulation type	Exterior wall finishing	Interior wall finishing	Interior floor finishing	Total U-Value
70.00 mm red block (lightweight)	40.00 mm EPS expanded polystyrene (standard)	10.00 mm cement/plaster/mortar	10.00 mm gypsum plastering	marble	0.59 W/m2K

The table (6-3) shows the types of construction and insulation materials for the existing villa. The external wall U-value is 0.59 W/m^2K. According to SEEC Jeddah is in zone 1 as shown in figure (6-6) the U- Value recommended by SEEC in stage one zone 1 is 0.53 W/m^2K and in stage two zone 1 is 0.34 W/m^2K. The U-Value figure for the existing villa (0.59 W/m^2K) is higher than both stage 1 and 2 (0.53 W/m^2K, 0.34 W/m^2K) respectively which indicates that the existing villa was built in 2006 before the climatic zone regulation was established.

Building element	Stage 1: ~ November 2014			Stage 2: January 2017		
	Zone 1	Zone 2	Zone 3	Zone 1	Zone 2	Zone 3
Roofs	0.31	0.37	0.42	0.20	0.24	0.27
Walls	0.53	0.61	0.7	0.34	0.40	0.45
Vertical Glazing , 25% of wall	2.67 SHGC- 0.25	2.67 SHGC- 0.25	2.67 SHGC- 0.25	2.67 SHGC- 0.25	2.67 SHGC- 0.25	2.67 SHGC- 0.25

Figure 6- 6 The new insulation regulation sets the min. U-values for new low-rise residential buildings. (source: SEEC,2010)

- ***Window Description***

Figure 6-7 showing the type of window on the chosen villa and the shading devices that residents use to increase levels of privacy. The residents use aluminium double-glazed glass and both curtains and blackouts to prevent the glare and ensure privacy with regard to outsiders.

Figure 6- 7 Interior and exterior case study villa windows

Figure 6- 8 Exterior view of the windows of the case study villa

- ***Air Conditioning Information***

According to the data, the residents use a central system which has a capacity of 540000 BTU.

Figure 6- 9 Case study villa living room.

The picture above shows a large glass window and the use of curtains and blackouts. As shown in the picture, the natural lighting through the glass window results in glare, which the residents use blackouts and curtains to prevent while at the same time increasing the level of privacy. The use of blackout darkens the indoor space which leaves residents with no alternative but to use artificial lighting even during the daytime, and hence increasing energy consumption further. In the picture, the blackouts are open because the researcher asked to observe the natural light that would otherwise enter the room. One of the functions of *mashrabiya* is to control the amount of light entering the house, so the problem of the glare from the sunrays would be solved, as would any privacy issues. Since this research seeks to determine the effectiveness of *mashrabiya* to reduce energy consumption, and restore privacy and identity, it is clear that their functions are highly likely to solve the issues listed above. *Mashrabiya* is made of wood, which has a lower U-value than glass, which in turn means this product would be energy efficient. On the other hand, the size of glass window results in more heat being transmitted, further resulting in high indoor air temperatures and residents making increased use of air conditioning to ensure indoor environmental quality.

- ***Electricity Bill***

Table 6- 4 Three-year period of energy consumption for the case study villa

Before the increase in electricity tariff		**After the increase in electricity tariff**	
Energy consumption	**Annual cost**	**Energy consumption**	**Annual cost**
98847 kWh	**10193 SR (2017)**	**95,805 kWh**	**18,703 SR (2018)**
		86,320 kWh	**16,925 SR (2019)**

The table above shows the case study villa's annual energy consumption and electricity costs before and after the increase in tariff of their Saudi Electricity Company account. According to the results, the energy consumed in 2019 decreased from 98,847 kWh to 86,320 kWh, a fall of 13%. Despite this, the annual cost increased substantially from 10,193 SR to 16,925 SR a total increase of 40%. The percentage of the annual electricity bill to the total annual income in 2017 before the increase in tariff was 3% however, after the increase in tariff in 2018 the increase doubled (6%) and remained almost the same in 2019 (5.6%) the changes in total increase or decrease is depended on household consumption.

Fig (6-10) represented by blue and orange bar graphs indicates the amount paid and the amount of electricity consumed, respectively. These bar graphs are a true reflection of the associated price and energy consumption for the case study villa after the increase in electricity tariff. The figures in the table (6-4) were calculated from the resident's electricity account before and after the increase in electricity tariff and the information is as summarised in the table above. During the interview, the interviewee noted that they used artificial lighting during both the day and evening, which is probably one of the reasons the electricity bill is this high. One of the reasons for using artificial lighting during the day is because the blackouts result in the room being dark, which is used to increase the level of privacy. According to the responses from the residents, the air conditioning is left on regardless of whether they are in or out of the room, which means it is used 24 hours a day on the first floor, which has four bedrooms and a living room. As stated previously, such a lifestyle will have a significant impact on energy consumption, where this family, having children, leave the air condition on and lock the door while they go to school so that the room is cool and comfortable on their return.

The annual cost of consumption and the amount of energy consumed before the increase in energy electricity tariff.

Figure 6- 10 Example of electrical energy consumption and associated costs for 2019- for the case study villa

Measurements Taken

Table 6- 5 Case study villa measurements

x	Outdoor	Living room	Unused room
Air Temperature	33ºC	23ºC	36ºC
Humidity	78%	53%	91%
Wind speed	0.9 – 1.7 m/s	0.1 - 0.3 m/s	0.1 - 0.2 m/s
Daylight with shatters	-	15 LUX	15 LUX
Artificial light	-	367 LUX	345 LUX

The table above shows measurements taken outdoors, and in the villas living room and unused room. The researcher focussed on air temperature, humidity, and air speed, as well as daylight and artificial light. Various types of equipment were used for the different measurements taken, for instance the researcher used a thermal detector to measure surface and room temperature and humidity (PTD1 BOSCH with degree Celsius as the unit of measurement with laser circle to indicate the area being measured). Unsurprisingly, outdoor temperature proved to be the second highest, at 33ºC. while the unused room was the highest at 36ºC, finally the lowest was the living room at only 23ºC. The percentage humidity was the highest in the unused room at 91%, while the living room was the lowest at 53% and where outdoor humidity was 78%.

In relation to wind speed, the researcher used a mini handheld anemometer for measurements which is said to be highly accurate especially due to the fact that it uses a magnetic sensor. Unsurprisingly, the windspeed figures show the outdoors to be the highest, ranging from 0.9-1.7m/s whereas the unused room was 0.1 – 0.2m/s. The wind speed in the living room had a range of 0.1-0.3 m/s. A 5unche digital light meter HS1010 was used to record lighting levels. The results showed natural light levels of 215 LUX and 15 LUX for the living room and unused room, respectively. Due to the brightness of the sunshine during the daytime the equipment failed to show a reading, hence the 0-LUX entry in the table above. The final measurement was that of artificial light, where the highest recording was for the living room at 377 LUX, followed by 345 LUX for the unused room (for obvious reasons, no outdoor measurements were taken).

Figure 6- 11 Devices used to measure the internal and external temperatures, lighting levels, and air speeds.

- ***Observation Data***

Table 6- 6 Case study villa observation data

Tick box table				
A.C Set point	20°C			
Room area	30 m^2			
Height of Ceiling	2.75 m			
Floor finishing and colour	Marble 'Rosa'			
Wall finishing and colour	Plaster light green			
Number of windows and area	3 windows, 5.76 m^2			
Type of glazing	Double glazed glass			
Window shading	Curtains	✓ Blackouts	Shutter	
Type of light	✓ Natural	✓ Artificial		
Type of artificial light use	✓ Florescent	✓ Halogen	LED	
Type of resident's clothes	cotton			
Resident's comfort	Yes			

The information collected from the case study through the interviews and observations is important input in design builder for simulation process. The information collected and used in design builder included the plan, location of the villa, the description and household characteristics. The construction and envelop material as well as measurements taken during observations all summed up data used in design builder Further input in design builder included the type of glazing and AC as well as operation times.

6.5 Design Builder and Case Study Villa Simulation

The case study plays a major role in this research to enhance virtual investigations using realistic figures collected through interviews including the plan. This inputted into design builder to assess indoor environmental quality. The simulation process is carried out with and without mashrabiya in the existing building while considering the factors such as lighting, operative temperature, solar gain, natural and artificial ventilation as well as total energy consumption and cooling load to investigate the impact of mashrabiya on energy performance.

6.5.1 Case Study Villa Existing Model Simulation

The Energy Plus software program (Design Builder) was used to model the case study villa. The AutoCAD suite of programs enabled the researcher to create a three-dimensional model of the villa case study. The data input for the modelled case study villa included results collected from both the interviews and observations. The simulated three-storey villa included two bedrooms on the annex, four-bedroom zone and a living room zone on the first floor, and a male and female guest room zone on the ground floor as well as the kitchen and dining zone. The cooling temperature set points were set to 16^{o}C to 20^{o}C in all zones.

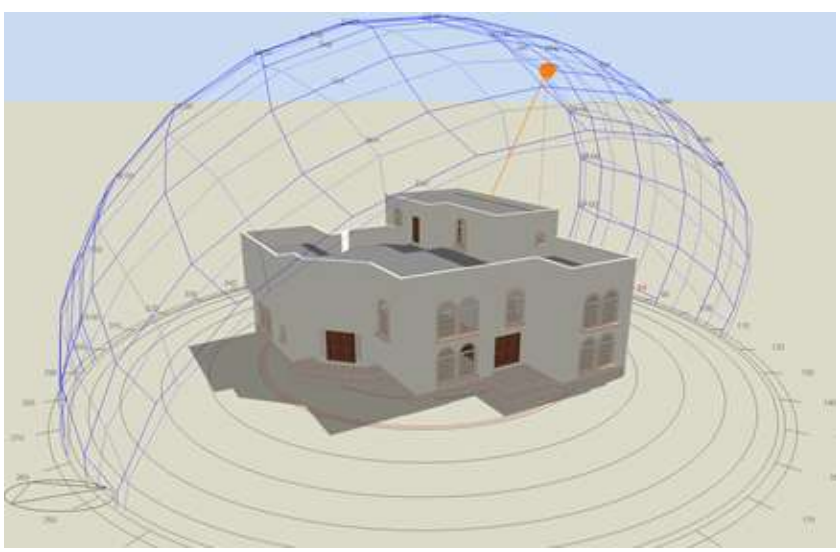


Figure 6- 12 Existing villa case study model as constructed in Design Builder.

Figure 6- 13 Existing case study villa and neighbours model as constructed in Design Builder.

Table 6- 7 List of input categories

Profile of Occupation.
Profile Lighting.
Profile of Electrical Equipment.
Profile Ventilation.
Profile of the temperature set point.
Profile of Shading.
Housing Opaque.
Geometric Modelling.
Thermal Zone.

- In relation to the occupancy rate in the rooms, the inputted figure of six people allowed the occupancy rate to be calculated as 0.0229 person/m^2 and the activity rate of occupants totalled up to 0.90 per person. The occupancy schedule was derived from the time duration, number of occupancies per week, and thermal zone.
- As far as lighting and internal gains were concerned, the figures for the installed power in various zones has been sized through simulations on artificial lighting. The lighting density is dependent on the area and varies from one thermal zone to another according to the specification of the room(s) concerned.
- The calculation of the appliance internal gains was based on the setting of installed power of 28 W/m^2) (100 LUX) for domestic dwellings.
- In relation to natural ventilation in the simulation, when the air condition was turned off the rate of air change was set to 3 (ACH).
- With regard to HVAC modelling systems, one of the Design Builder HVAC templates was selected for use in our simulations, in particular the VAV Air-cooled chiller. HR. Outdoor air reset. HVAC is an acronym for heating, ventilation, and air condition systems. The Coefficient of Performance (CoP) for the cooling system, (air conditioners) was set to 3.8 (CoP) according to the results from the villa case study. The functions of the CoP were calculated to determine the performance of the AC system, starting from Jeddah's climatic data (wet and dry bulb temperature of the air). For mechanical ventilation, the rate of air change was set to 3 (ACH).
- After the selection of the set points, the local shading, as one of the Design Builder parameters, was selected to give monthly and annual schedules for sun patches. Regarding the system modelling of the villa case study, one of the Energy Plus HVAC templates was adopted.
- The thermal zone is King Abdul Aziz international airport, Jeddah.

6.6 Existing Villa Simulation Results without AC (Natural Ventilation)

6.6.1 Day Lighting Factor

The diagram below represents simulation results for the average amount of daylight factor on the ground, first and second floor in the existing case study villa with double glazed windows, measured in LUX. According to (Grondsik et al., 2011) daylight factor (DF) is defined as the ratio of interior illuminance (E_i) to available outdoor illuminance.

As reported by BREEAM standards the acceptable average daylight factor is at least 2% in the living rooms, dining rooms and BREEAM standards confirm that studies achieve a minimum average daylight factor of at least 1.5% of which 80 % for the working plane should receive direct light from the sky. The results show the highest amount of daylight factor on the ground, first and second floor as 1.56, 1.58 and 1.57 LUX, respectively. The results indicate that the residents have enough daylight factor through the double-glazed windows however, in an attempt to provide privacy, they use curtains, blackouts and shutters as a result they do not receive natural light.

Table 6-8 Design Builder input for simulation daylight

Glass window						Artifi-cial lighting	Outdoor air temper-ature
Type	**Opened/ Closed**	**Curtain Open/Closed**	**Solar transmission (SHGC)**	**U Value (W/m2-k)**	**Air change rate**	**On/Off**	**The monthly average**
Double glazed windows	Closed	Fully opened	0.223	2.874	3 (AHR)	Off	between November and March

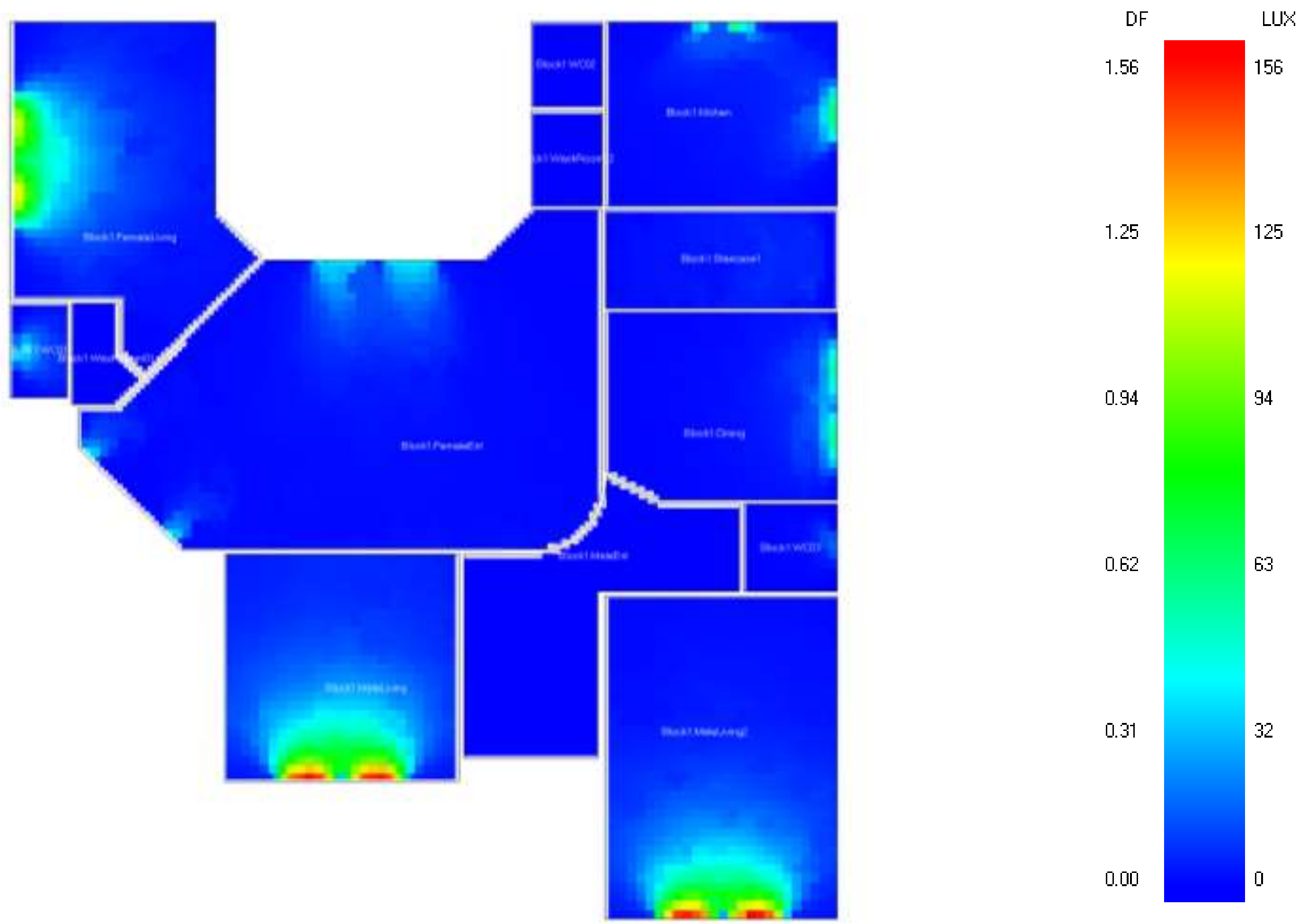


Figure 6- 14 Daylight factor for ground floor existing case study villa

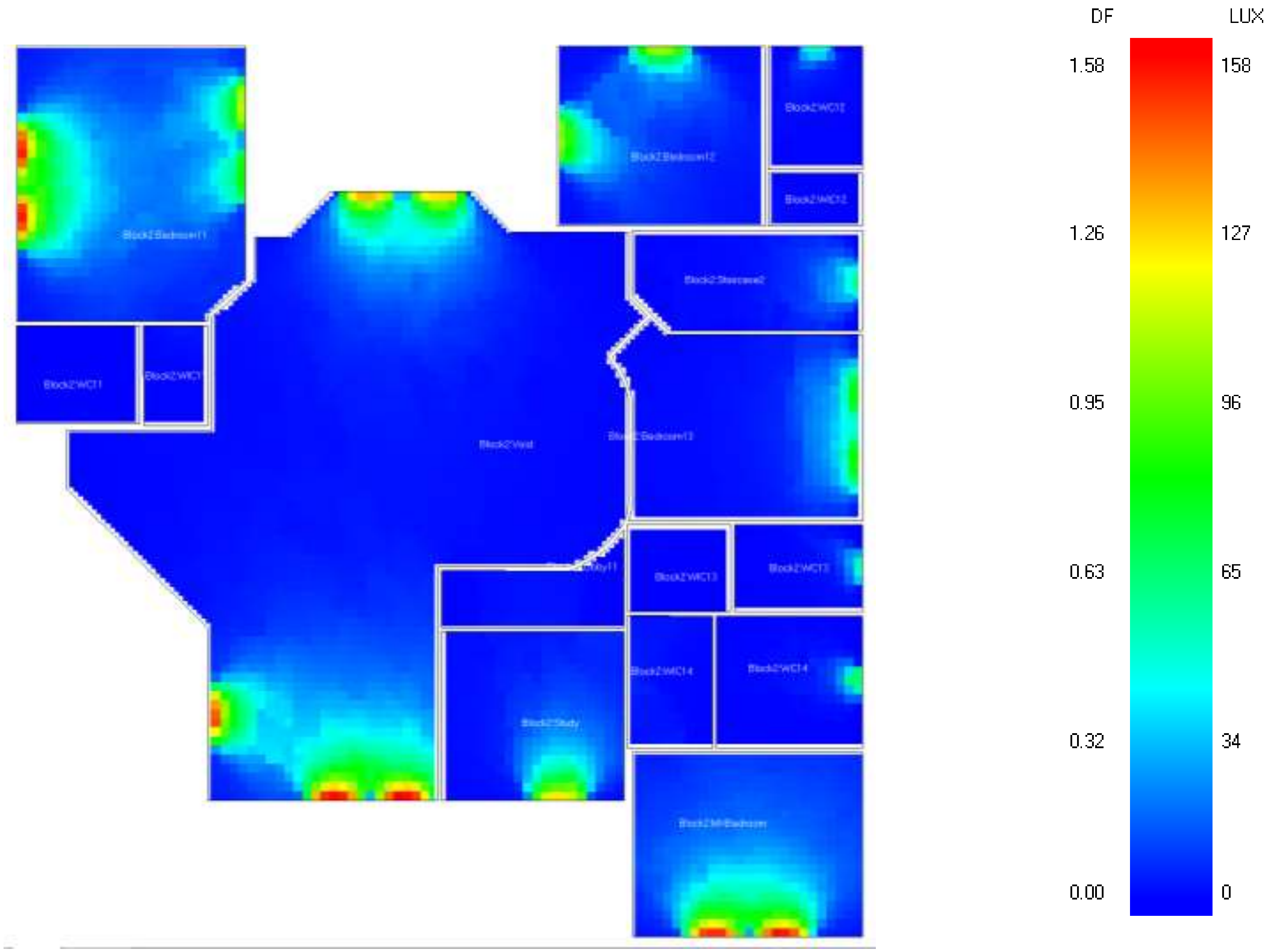


Figure 6- 15 Daylight factor for First floor existing case study villa

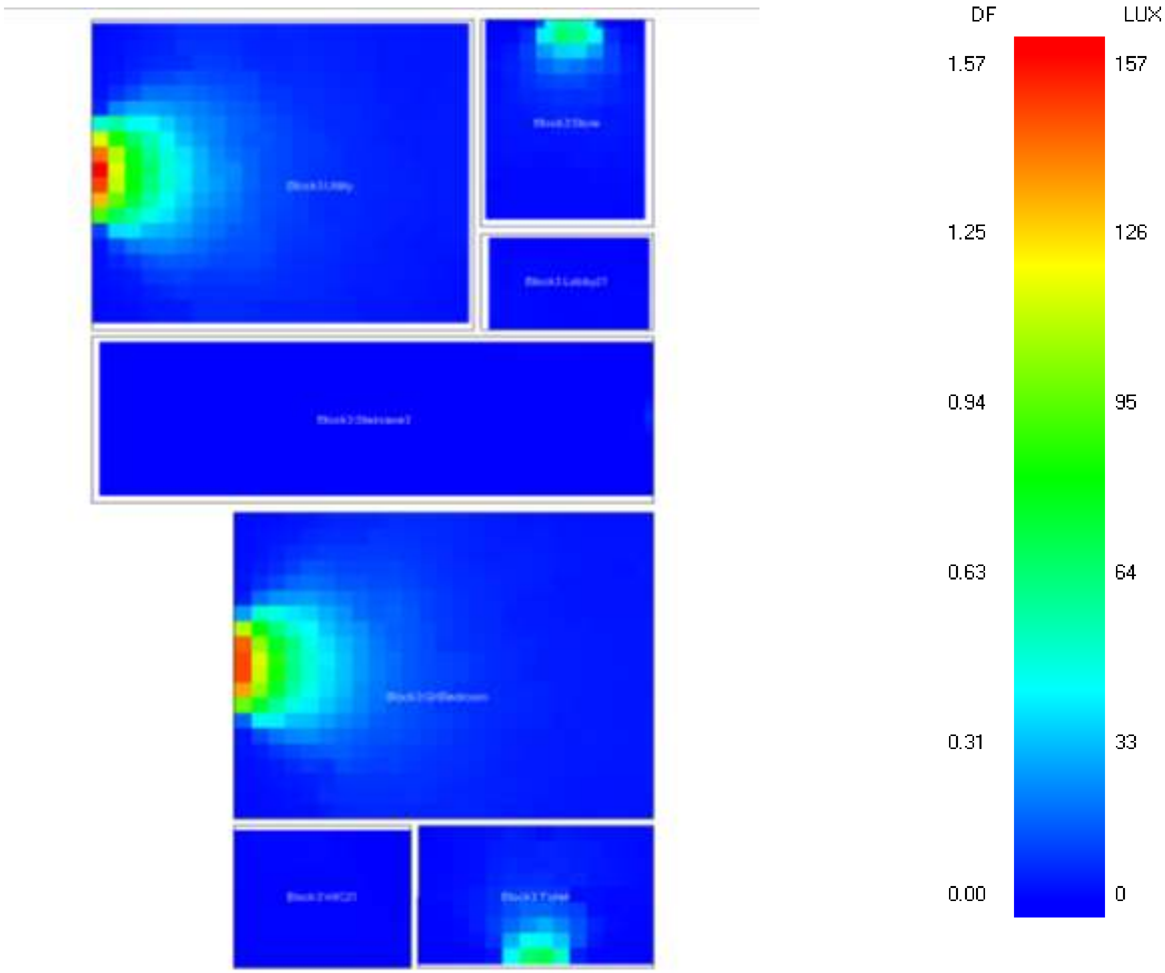


Figure 6- 16 Daylight factor for Second floor existing case study villa

6.6.2 Indoor Operative Temperature without AC (Natural Ventilation)

Table 6- 8 Indoor Operative Temperature without AC

	Jan	Feb	Mar	Nov	Dec	Average Temperature
outside dry bulb temp (°c)	**22.79**	**23.57**	**25.04**	**26.87**	**25.05**	**24.66**
The base case villa with 'double glazing window'	**27.72**	**28.74**	**30.22**	**32.41**	**30.21**	**29.86**

The table (6-8) above is a representation of indoor operative temperature without air condition (AC) natural ventilation in a base case villa with double glazed windows. The results recorded from simulation are taken during the period between November to March. According to ASHRAE standards the recommended indoor operative temperatures ranges from 20.3 ^{0}C to 23.9 ^{0}C in the winter, and from 21^{0}C to 27 ^{0}C in the summer. According to the results the outside temperatures are within acceptable comfort zone ranging from 22.79 to as high as 26.87 ^{0}C. Whereas the indoor operative temperature with windows opened as wide as 50% reflected the uncomfortable temperatures ranging between 27.72 reaching the highest of 32.41^{0}C.

6.7. Existing Villa Simulation Result with AC

6.7.1 Artificial Lighting

The table (6-9) below shows simulation results for the annual total energy used for artificial lighting in all the simulations for the existing building with double glazed windows. According to the results, the annual total energy usage is 51,302.05 kWh, which remains constant throughout the simulation phases because of the use of window treatment such as the curtains, shutters, and blackouts. This is also supported by the results from the Jeddah Municipality interviews, who rated lighting as the second highest contributor to the increase in energy consumption. In addition, from observation, it was clear that the majority of residents used both artificial lighting such as halogen and florescent although halogen is used more than fluorescent and unnecessarily in addition, curtains are never opened. According to the simulation results, artificial lighting consumes almost the same amount of energy as cooling in base case, with only a difference of 667.04 kWh. It might also be noted that the total energy used for lighting may increase or decrease depending on the type of bulb used. (See 6.7.4 cooling load)

Table 6- 9 The annual total energy usage for lighting

Annual energy usage for lighting
Lighting (51,302.05 kWh)

Table (6-9) above shows the total energy usage for lighting for the whole year in the base case.

6.7.2 Indoor Operative Temperature with AC

Table 6- 10 Indoor Operative Temperature with AC

	Apr	May	Jun	Jul	Aug	Sep	Oct	Average Op Temp °C
outside dry bulb temp (°c)	**27.63**	**30.57**	**31.01**	**33.16**	**33.13**	**31.13**	**29.87**	**30.93**
Indoor operative temperature for base case ‘double glazing window’	**26.46**	**27.30**	**27.55**	**28.14**	**28.25**	**27.83**	**27.24**	**27.54**

The table (6-10) above shows a summary of indoor operative temperature with air conditioning (AC) for the period of April to October with a fixed set point of 16 °C and set back at 20 °C. Operative temperature in Design Builder is the average of the indoor air temperature and radiant temperature. According to the simulation results in the existing villa with double glazed windows, August has the highest operative temperature at 28.25°C while April has the lowest at 26.46°C. The average operative temperature for the selected months is 27.54°C.

6.7.3 Solar Gains Exterior Windows.

Table 6- 11 Solar Gains Exterior Windows (kWh)

Annual %	Annual solar gain	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
outside dry bulb temp (°c)		22.79	23.59	25.04	27.63	30.57	31.01	33.16	33.13	31.13	29.87	26.87	26.05
 Existing building 'double glazing window'	3 320	290.23	280.15	279.01	258.60	317.48	312.57	299.50	245.69	260.79	255.39	259.03	258.08

The table (6-11) above is a summary of the simulation for solar gains in exterior windows measured in Kilowatt hours in the existing villa with double glazed windows. The simulation shows that the annual solar gain in the existing villa is, at 3,320 kWh. According to the results the months between May to July have the highest solar gain which indicates the amount of heat gained by the glass windows and affects the indoor temperature.

6.7.4 Cooling Load

The table below reports the results from simulation of how much energy is consumed in cooling the indoor environment in an existing villa with double glazed widows. According to (Binggeli, 2010) the cooling load is the energy used to counterbalance the heat gained through the building envelope or through infiltration or ventilation in a hot climate. The results focus specifically on the months between April to October as the outside temperatures are well above the range of human comfort of 21 to 27°C, which results in high demand with regard to the use of AC, which draws more energy to cool the interior. The AC was set at 16^0 C and the setback fixed at 20^oC. The outside temperature in the months from November to March are within the range of human comfort, during which merely opening the window will provide further comfort. The energy usage to cool the existing villa that is, with double glazed windows in the months mentioned above is 42,155 kWh.

Table 6- 12 Total energy usage for mechanical cooling system

Total energy usage for mechanical cooling of the indoor environment for the months from April to October		
	**Existing building 'double glazing window'**	**42,155 kWh**

6.7.5 Total Energy Consumption

The table below shows the simulation results for the total amount of energy consumed in the case study villa with double glazed windows including the use of air condition, appliances, and artificial lighting. The results show the annual total energy consumed as 106 114 **kWh**.

Table 6- 13 Annual total Energy consumption

Annual total Energy consumption		**kWh**
	**Base case 'double glazed window'**	**106,114**

6.8 Conclusion

This chapter shows all the data collected in relation to the case study villa through the interviews and observations as well as photos and measurements taken. Simulation process using the energy Plus software program (Design Builder) included villa information investigating factors that impact on building energy performance. The results of simulating the existing case study villa with double glazed window will be discussed and compared after adding wood and gypsum mashrabiya in chapter seven. The simulation results for the base case with double glazed window indicate that the residents have sufficient day light factor hence have no reason to use artificial light. On the other hand, the simulation for the base case for day light with AC showed excessive use of artificial light. In relation to operative temperature without AC, it is apparent that the results showed uncomfortable indoor environmental quality in addition, the operative temperature with AC also produced undesirable indoor environmental quality for residents. The simulation results for solar gain on the base case indicated highest levels between May to July.

CHAPTER SEVEN

7. New Mashrabiya Design and Material

7.1 Mashrabiya Design Process

The previous chapter simulation of base case with double glazed windows is the calibration process revealing the closeness of results to the existing building accuracy of design builder. This refurbishment process of mashrabiya includes the change of material, a simplified design as well as the material as per recommendations from the interviews and online responses. According to the interviews and online responses, mashrabiya would be considered if it were redesigned and material changed to suit modern style as well as not only affordable but also locally produced. The base case will be simulated with the effective refurbished mashrabiya to find the differences in energy usage to the base case villa without *mashrabiya*.

7.1.1 Mashrabiya Dimensions

The dimensions used for the structure of the *mashrabiya* in this research are within the range of the traditional *mashrabiya* which typically measures 2.4-2.8 m in width, 0.4-0.6 m for the projection depth, and 2.07-3.50 m for in height; however, the height and width may increase depending on the type and thickness of wood used (Alitany, 2014). The *mashrabiya* design for this research uses measurements that fall within the range of traditional *mashrabiya* which are comprised of squares and rectangles. A complex structure of *mashrabiya* comprises various structural and more minor features. However, for this research, a simple design structure has been selected to satisfy the needs of the residents according to the responses from the interviews and online questionnaires, where residents recommended a simple design and a change to the traditional material. *Mashrabiya* are divided into three main parts including the head, which has two parts, the body, which is also divided into two, and the bottom, which is also two parts.

Figure 7- 1 Examples of traditional Mashrabiya 'Roshans' Source: (Alitany, 2014)

The dimensions of the simple *mashrabiya* in this research follow the three-panel structure as recommended by (Alitany, 2014, p.105) where the width is three panels which measure 1.56 m in total, the width of one panel is 0.66 m, and the height is five sections, which measure 3 m in total. The measurements used for the *mashrabiya* were changed to suit the size of the window of the villa case study.

Mashrabiya designs one and two for this research included a variety of shapes such as squares, circles, rectangles, and diamonds. The sizes of the shapes differed between each design for instance the small hole diamond design on the head measured 5 by5 cm. The first part in the body of the mashrabiya composed of rectangles measured 7 by 74cm while the second part measured 7 by 65cm. on the other hand, the large hole design on the head measure 10 by 10cm for the diamonds and the first part of the body measured 16 by 74cm and the second part of the main body measured 16 by 65cm.

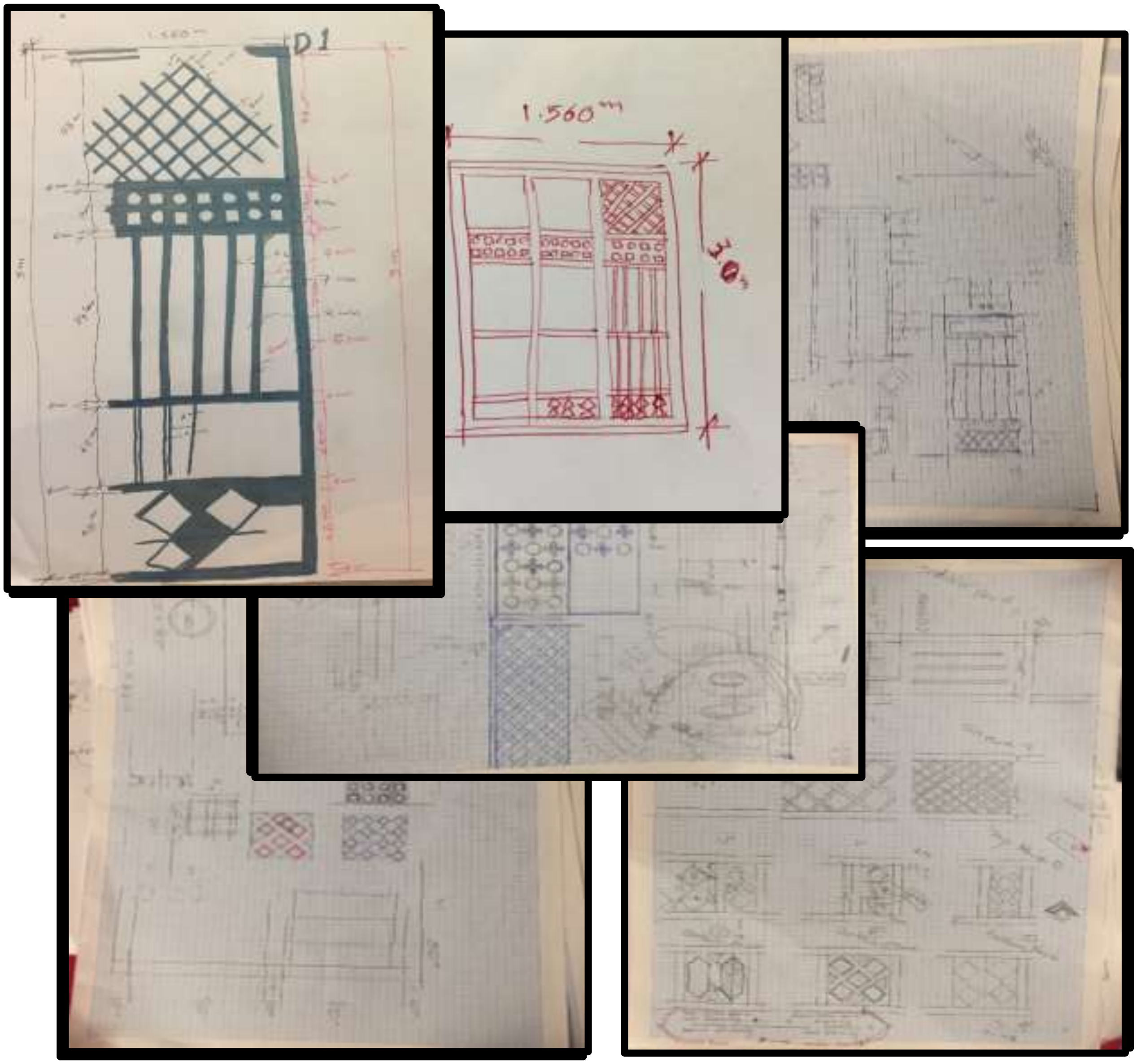


Figure 7- 2 Personal drawings of Mashrabiya designs

7.1.2 Mashrabiya Design

Figure (7-3) below are representations of a *mashrabiya* design as used in Design Builder. The Design Builder program is not capable of designing *mashrabiya* itself, hence the design process took longer than other architectural software programs for example AUTOCAD. The first picture (a) is a complete panel with frames on all sides, which means it can be used in the middle of the facing of *mashrabiya* however, the second picture (b) which has three frames can only be used on the sides to complete the width and as depth on the edges. As seen on the picture (c1) the top and bottom part of *mashrabiya* has no holes as this panel functions as a protector from the rain. Picture (c1) is a complete design facing the exterior of the building and the last picture (c2) is also a complete design of a new *mashrabiya* with an interior view.

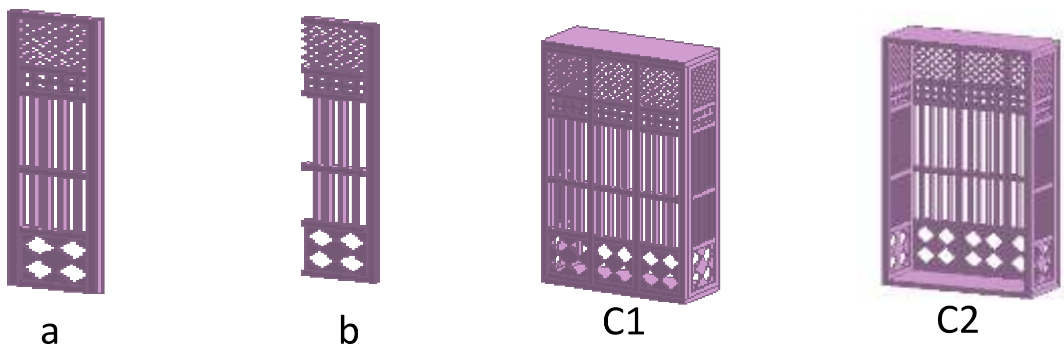


Figure 7- 3 Panels used for the mashrabiya model.

Figure (7-4) shows a complete *mashrabiya* size and design and how it was fitted in the exterior in all the windows in design builder base case villa with double glazing. while figure (7-5) is the model of the existing villa case study with double glazing and wooden *mashrabiya*. Figure (7-6) shows the model of a complete villa case study with coloured gypsum *mashrabiya*.

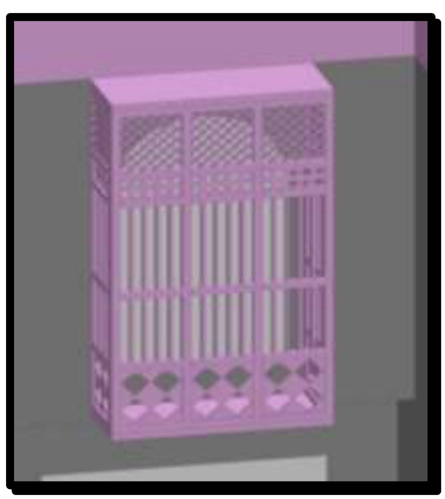


Figure 7- 4 complete mashrabiya design, showing how it should be fitted over the window.

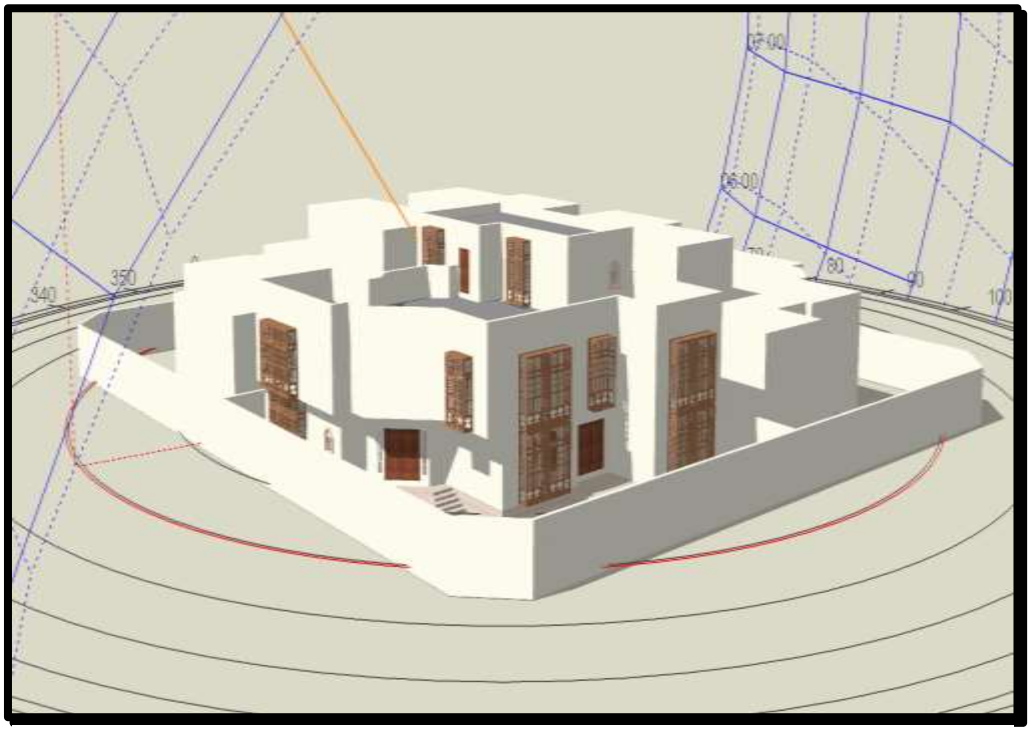


Figure 7- 5 View of existing case study villa with wooden mashrabiya, design 2

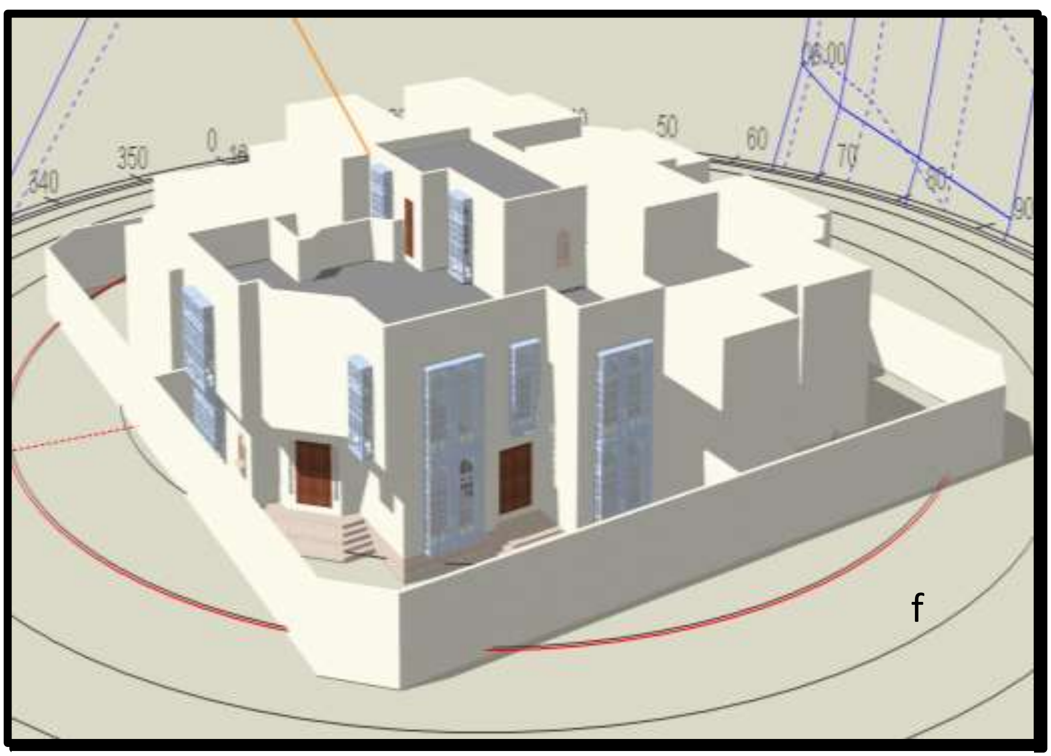


Figure 7- 6 View of existing case study villa with Gypsum mashrabiya, design 2

7.1.3 Mashrabiya Materials

Over the years wood remained the ultimate material for mashrabiya, however due to its properties including the fact that it burns easily, costly and has become unpopular among residents as reflected by the interviews has resulted to the change in material.

Gypsum is naturally available in Saudi Arabia and has long been used for decoration inside and outside buildings, whether for residential or for commercial purposes. Gypsum is easily formed and cut to produce complex shapes for various uses.

With regard to *mashrabiya*, gypsum can represent a good choice in terms of cost, durability, and sustainability. In terms of cost and mass production, gypsum is many times cheaper than wood and, since gypsum is produced using readymade forms, this represents a considerable advantage when we compare this to the need to craft every piece of wooden *mashrabiya*.

Figure 7- 7 Designed gypsum material panels.

Local contractors estimated a cost of 110-400 SR (25-85 GPB) per square metre for the production of gypsum *mashrabiya*, which is much cheaper than the cost of their wooden counterparts.

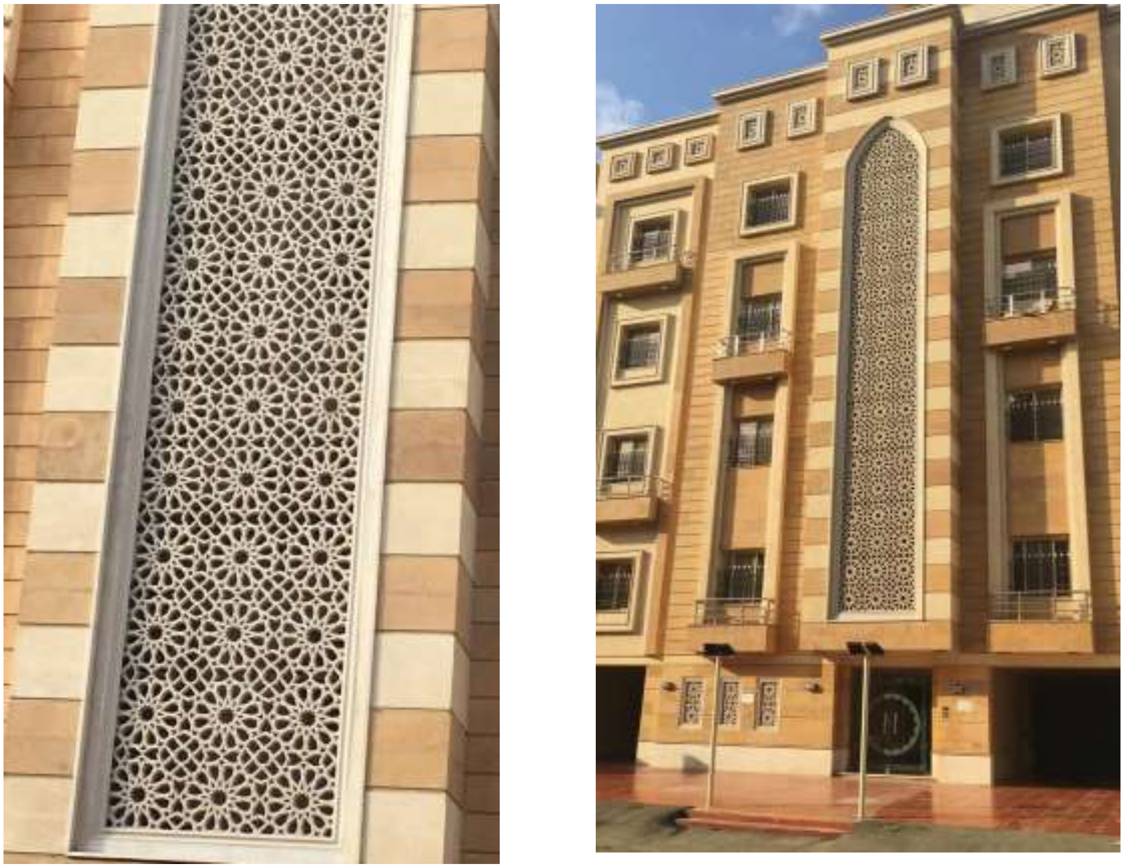


Figure 7- 8 Gypsum work in modern multi story building in Jeddah

Gypsum *mashrabiya* are more compatible with the other design elements inside the house such as suspended ceilings or wall ornamentations.

Gypsum *mashrabiya* can be produced with many different ornamentations and the local market has plenty of shapes.

Table 7- 1 Comparison between the properties of wood and gypsum

	Wood	Gypsum
Thermal conductivity (W/m-K)	0.14	0.70
Specific heat (J/kg K)	2301	1150
Density (kg/m$^{3)}$	510	640
Vapor resistivity (MNs/g)	150	10
Thermal absorptance	0.9000	0.9000
Solar absorptance	0.600	0.700
Visible absorptance	0.600	0.700

The table (7-1) above is a comparison between wood and gypsum for seven chosen features of interest. According to the table, the thermal conductivity for gypsum is 0.7 W/mk, and for is wood, 0.14 W/mk, while the two has the same thermal absorptances of 0.9. In relation to density, gypsum is heavier than wood by just over 20% for a given volume.

Table 7- 2 the reasons for the choice of gypsum over wood for the remodified mashrabiya

Wood	Gypsum
Imported material	Local material, exporter
Environmentally friendly	Environment friendly, organic
High cost	Low cost
Burns easily	Fire resistance
Absorbs water / hydroscopic	Water resistant when appropriately treated
Wood cannot be mixed with other products	Gypsum can be easily mixed with exodora, which increases resistance to humidity
Porous material	Porous material and has 3% water content
Bad conductor of heat	Bad conductor of heat
Expensive to make, also imported	Cheaper to produce and locally made. Affordable and available labour force

Table (7-2) above shows the reasons for the choice of gypsum over wood for the remodified *mashrabiya*. According to the table, wood is not suitable because of its lack of local availability and hence it is expensive, whereas gypsum can be locally produced which makes it much more affordable. One of the properties of wood is that it burns easily and hence is not suitable for modern buildings, while gypsum is fire resistant. While both wood and gypsum can absorb water, but wood obviously cannot be mixed with other products to improve its physical properties, whereas gypsum can be mixed with exodora to increase its resistance to humidity. Both wood and gypsum are porous materials, but gypsum retains a 3% water content which can be beneficial for cooling indoor temperature.

7.2 Base Case Villa with mashrabiya Simulation Results without AC (Natural Ventilation)

7.2.1 Day Lighting Factor

Table 7.3 Design Builder input for simulation daylight

Glass window					Outdoor air temperature
Type	**Opened/Closed**	**Curtain Open/Closed**	**Solar transmission value**	**Air change rate**	**The monthly average**
Double glazed windows with wooden and Gypsum mashrabiya both design 1 small holes and design 2 large holes	the double-glazed window is 50% opened for both mashrabiya design 1 with small holes and 2 with large holes.	Fully opened	For Wood 0.780 For Gypsum 0.700	3 (AHR)	between November and March
			Fixed parameters from design builder		

Figures (7-10, 7-11, 7-12, 7-13) is a demonstration of the natural day lighting access through *mashrabiya*, design 1 and 2, as well as the type of material used. In the existing villa, the day lighting is almost not due because of the use of windows treatments such as curtains, blackouts, and shutters, according to the interviews, the residents use window treatments during the day which blocks out any natural daylight. In the simulation, the use of *mashrabiya* has a noticeable impact on the amount of daylight in the indoor environment; this also depends on the floor of the villa, as the ground floor tends to receive minimal lighting due to neighbouring buildings. In relation to the use of designs and materials, these show the differences in the amount of daylight. For example, in the first situation, the design was fixed to examine the material of *mashrabiya*, which showed that wooden *mashrabiya* design 1 has a lower DF of 0.52 and 51 LUX while gypsum *mashrabiya* with the same design has 0.60 DF and 60 LUX, which indicates the effectiveness of gypsum as a material since its colour reflects light while wood absorbs light. When the material was fixed to investigate the effectiveness of the *mashrabiya* design, gypsum was chosen due to the previous results. Gypsum *mashrabiya* design 1 allowed 0.60 DF and 60 LUX, while design 2 with the same material has 0.66 DF and 66 LUX which confirm that gypsum *mashrabiya* design 2 is slightly effective in relation to daylight. The amount of daylight entering this case study villa is not satisfactory; however, this can be improved by increasing the size and number of openings.

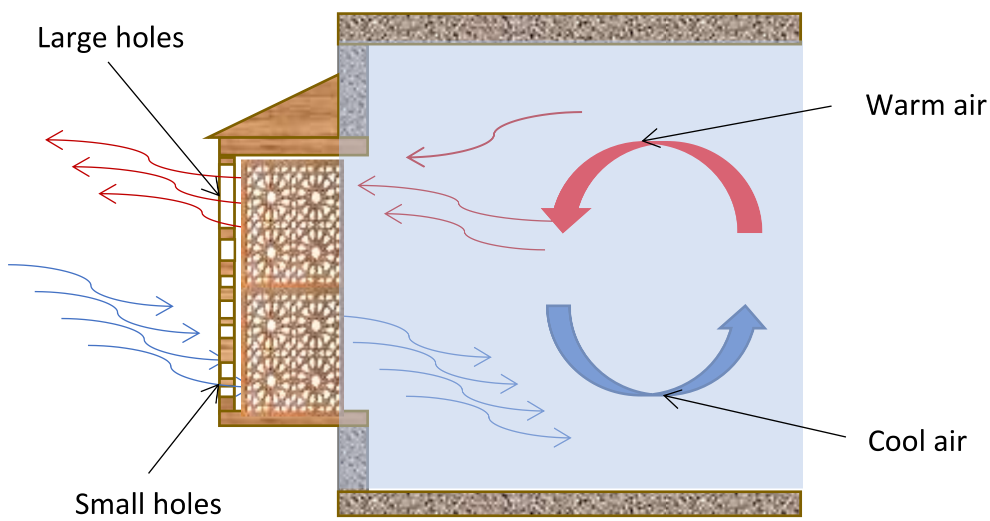


Figure 7-9 Cross ventilation through a single opening (Source: Alghamdi, S. 2019).

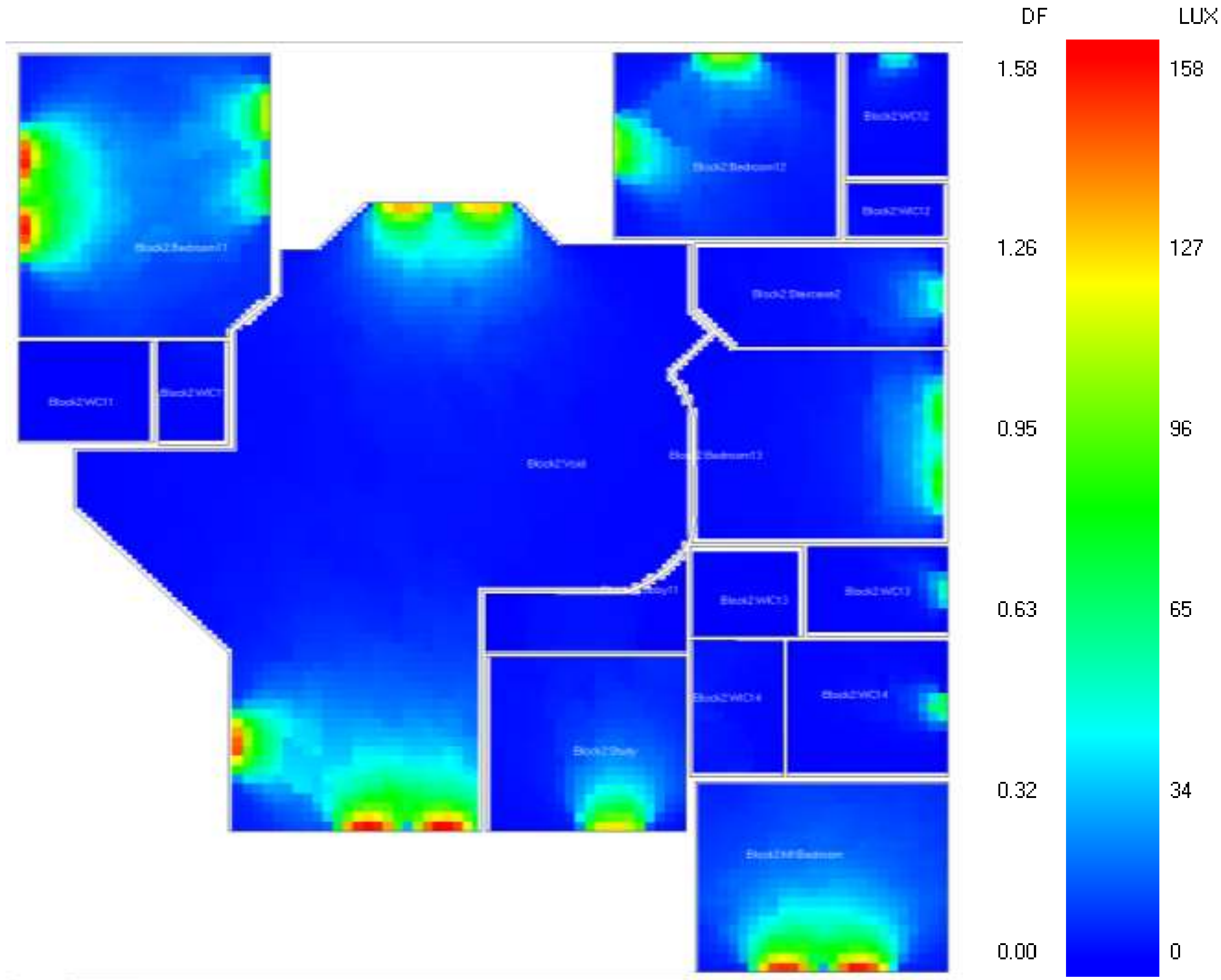


Figure 7- 10 Daylight with double glazed windows

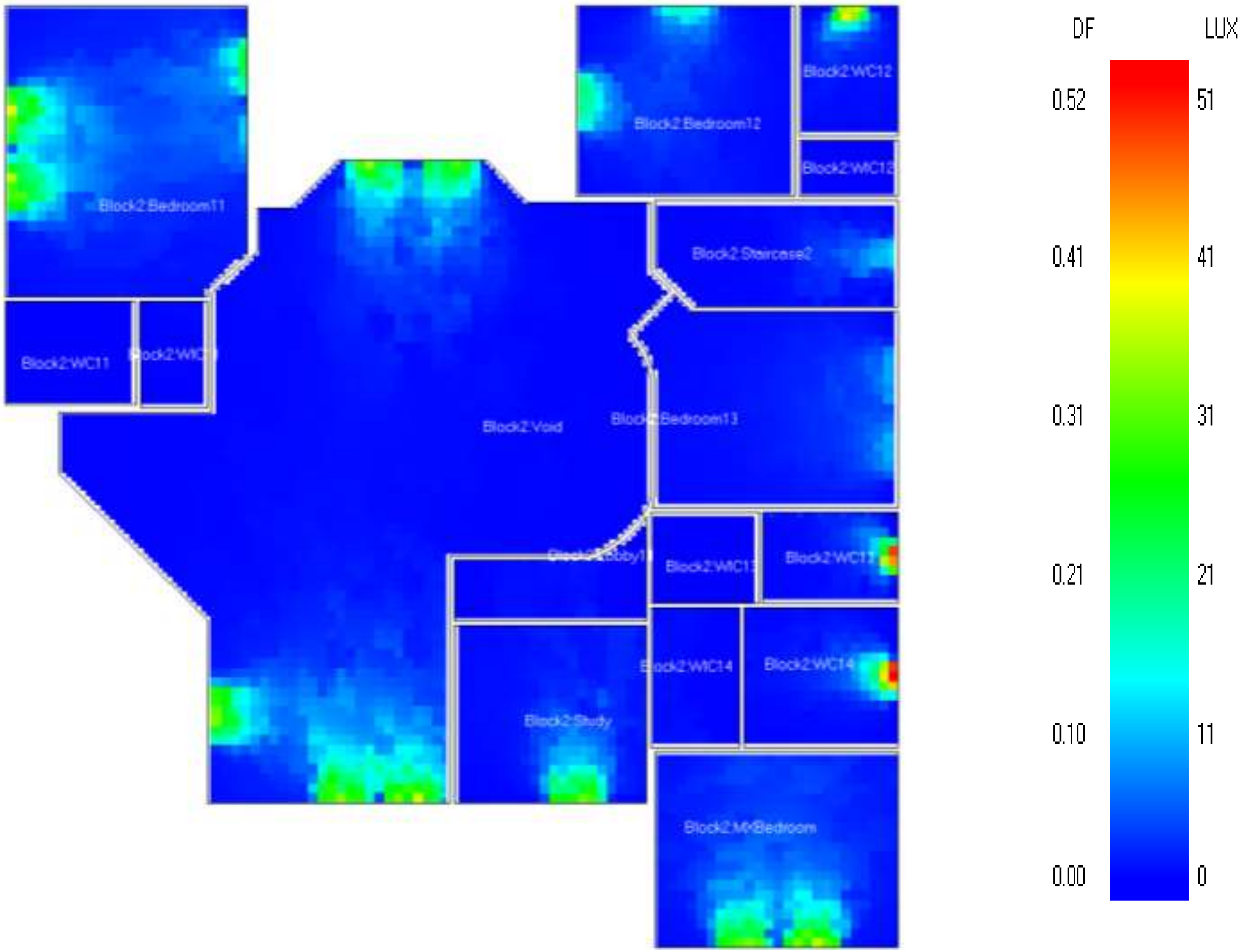


Figure 7- 11 Daylight with wooden mashrabiya design 1

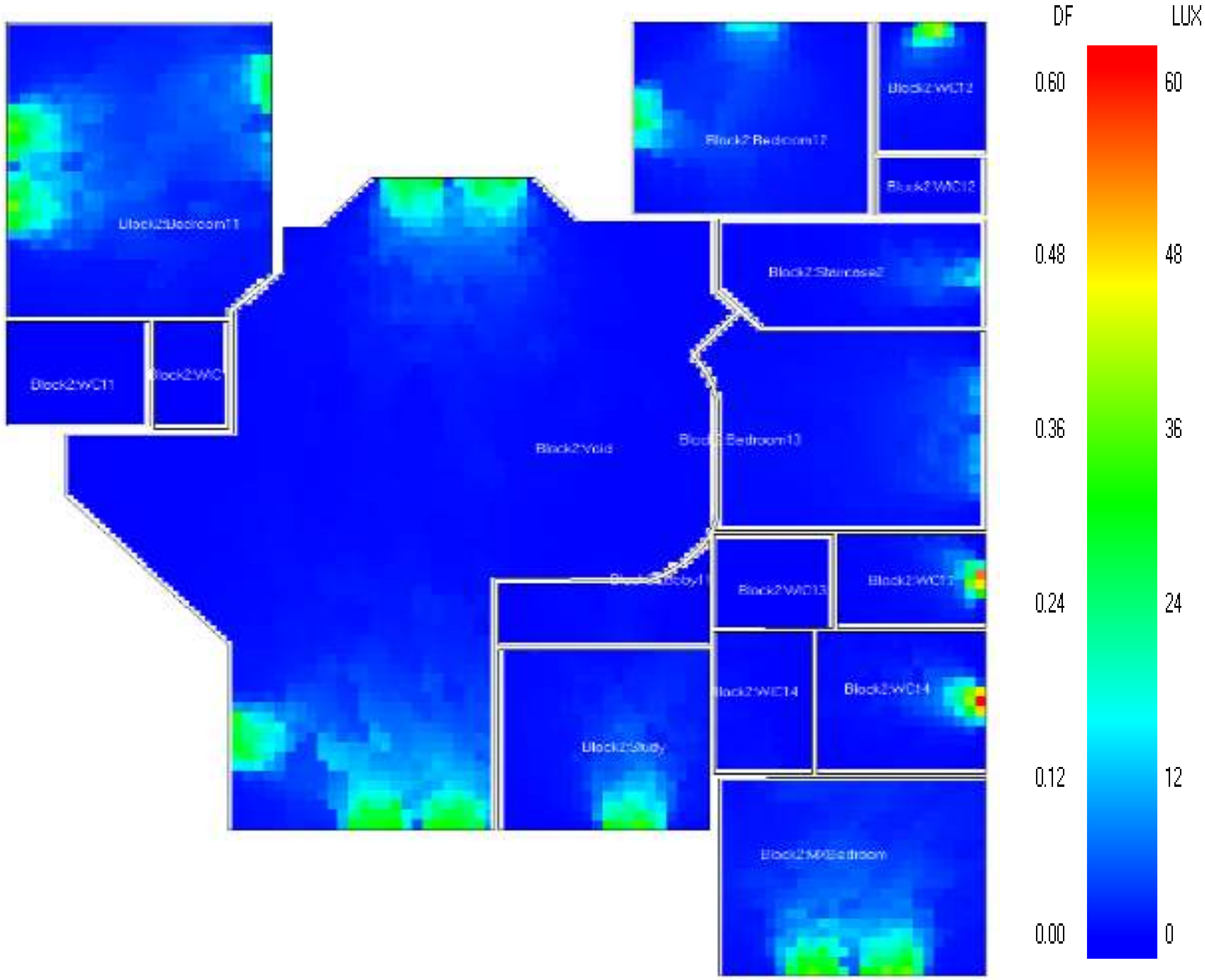


Figure 7- 12 Daylight with gypsum mashrabiya design 1

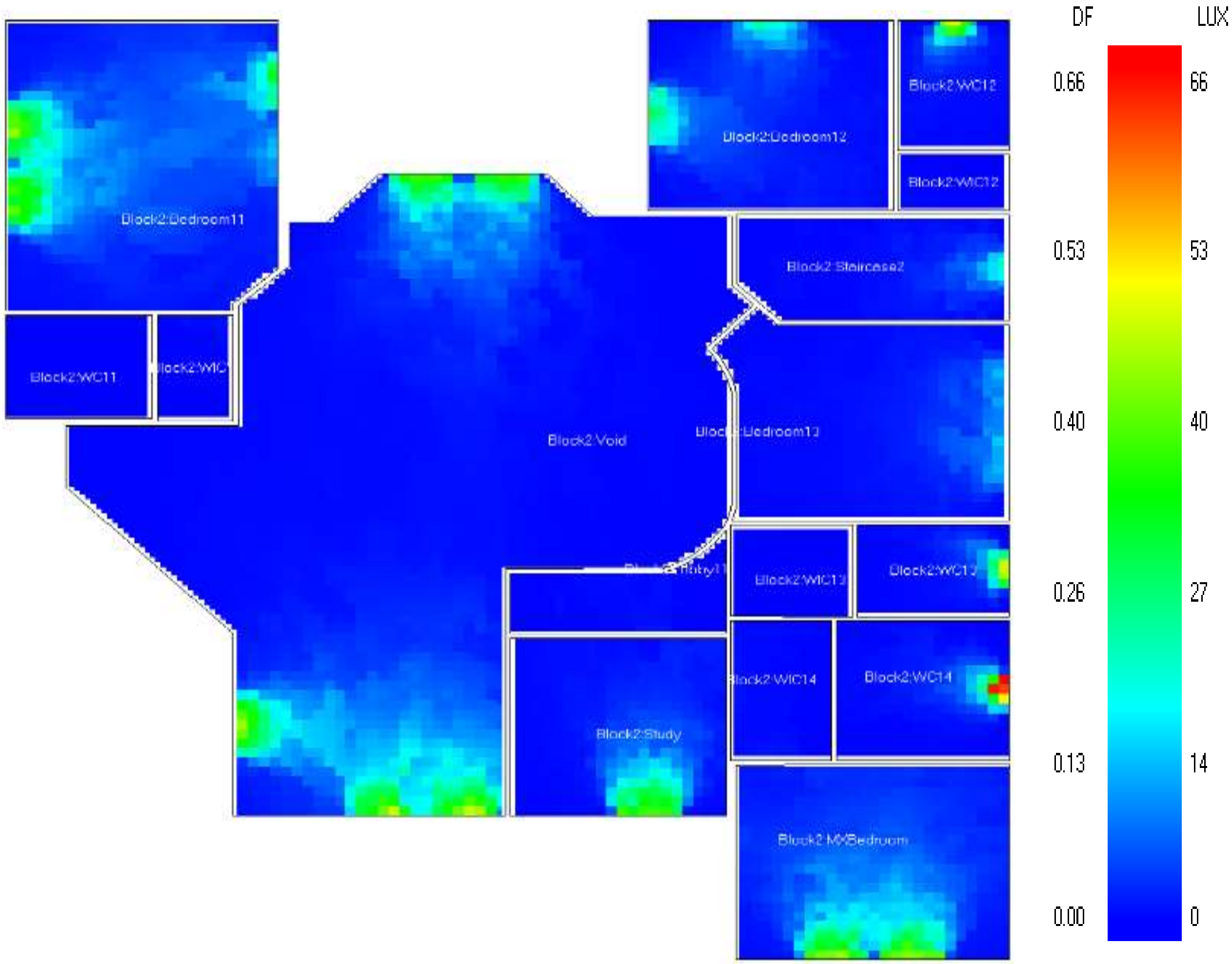


Figure 7- 13 Daylight with gypsum mashrabiya design 2

Daylight factor in the living area

The diagrams 7-14 to 7-18 below are a representation of the outcome of more simulations carried out to investigate the distribution of the day light factor in the living room while the artificial light was turned off in the base case with double glazed windows. Further investigations included the base case villa with double glazed windows and addition of wooden and gypsum mashrabiya design 1 and 2. The illuminance levels were calculated using Design Builder. It is clear from the diagrams that the illuminance levels in the living room are not reflective of the standard according to BREAM. The daylight factor in the base case villa is below the expected standard according to BREAM due to the number and size of windows as well as orientation and the external obstructs for example the neighbours. The inclusion of wooden and gypsum mashrabiya design one and two reduce day light factor to the worst however, this can be resolved by increasing the size of holes and the number of windows.

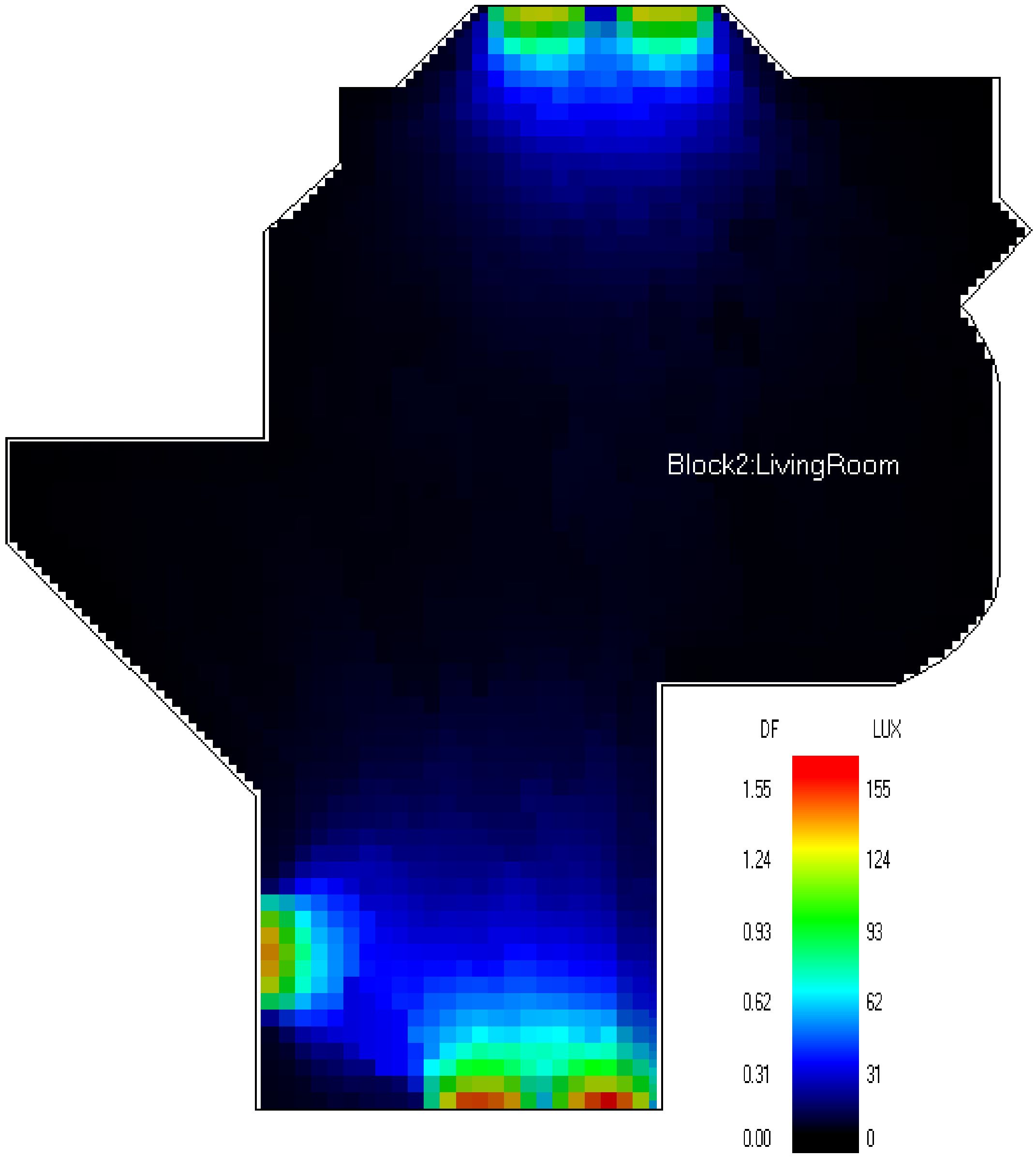


Figure 7-14 Existing villa base case living area daylight

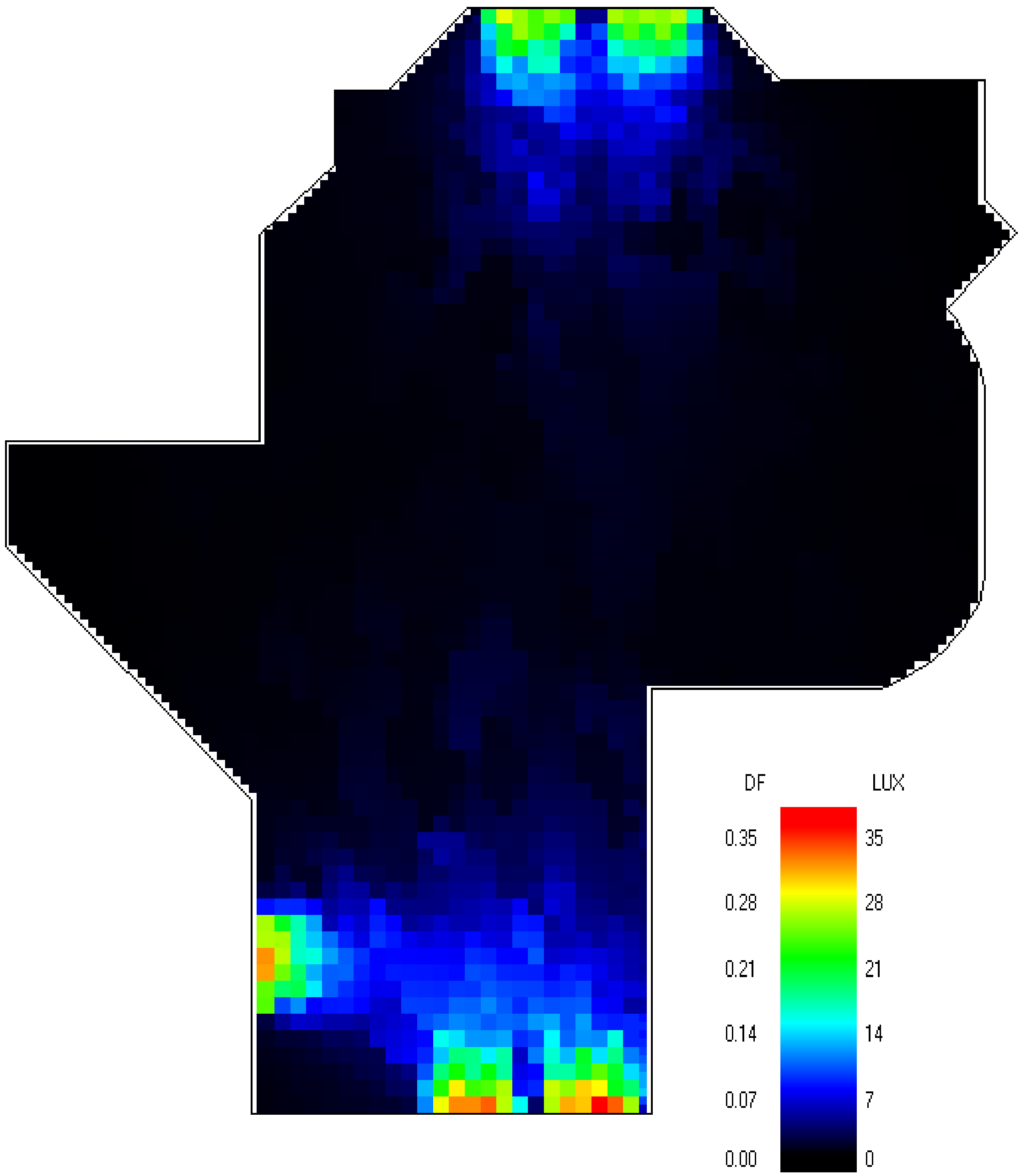


Figure 7-15 wooden mashrabiya design 1 living area daylight

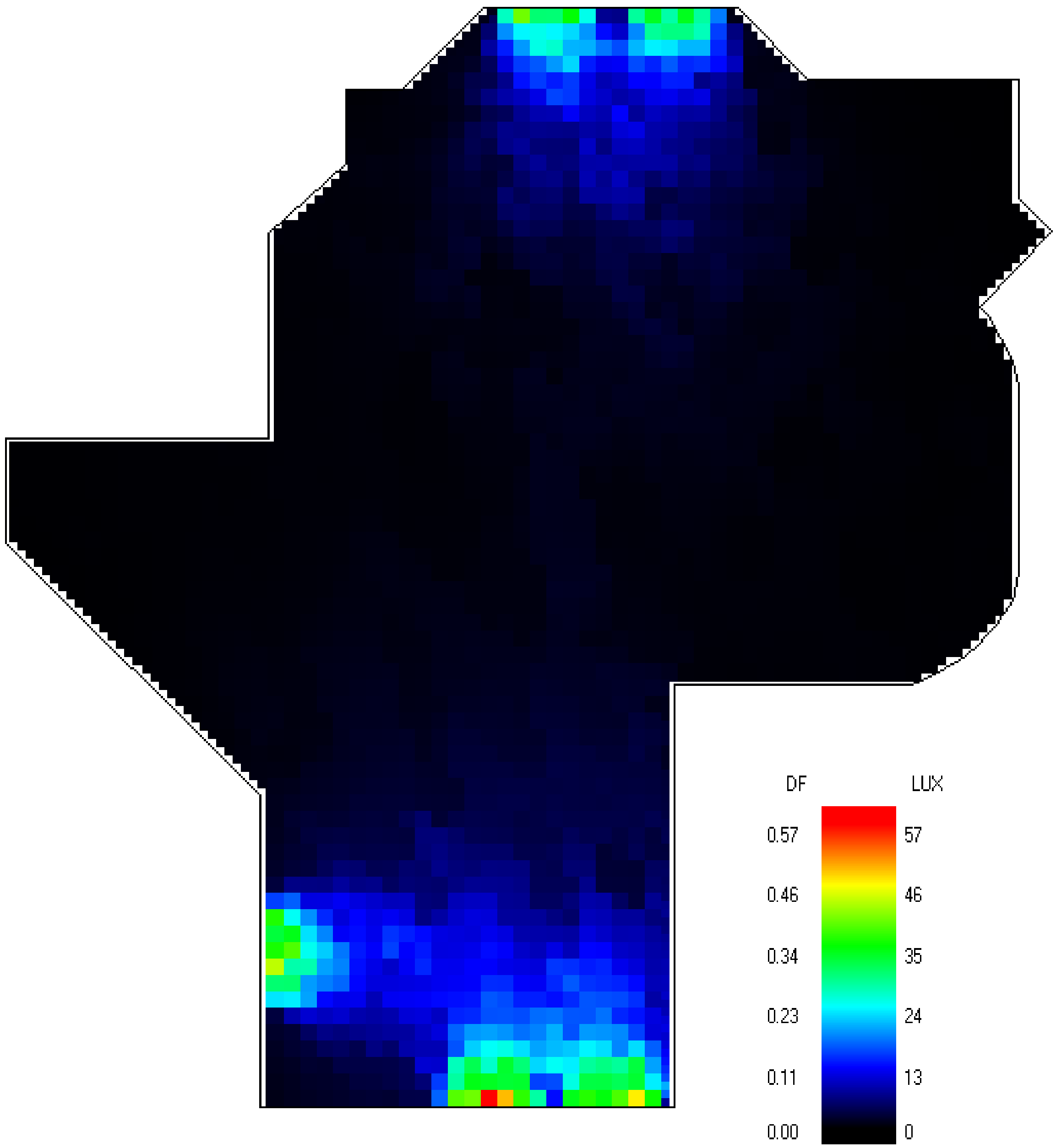


Figure 7-16 wooden mashrabiya design 2 living area daylight

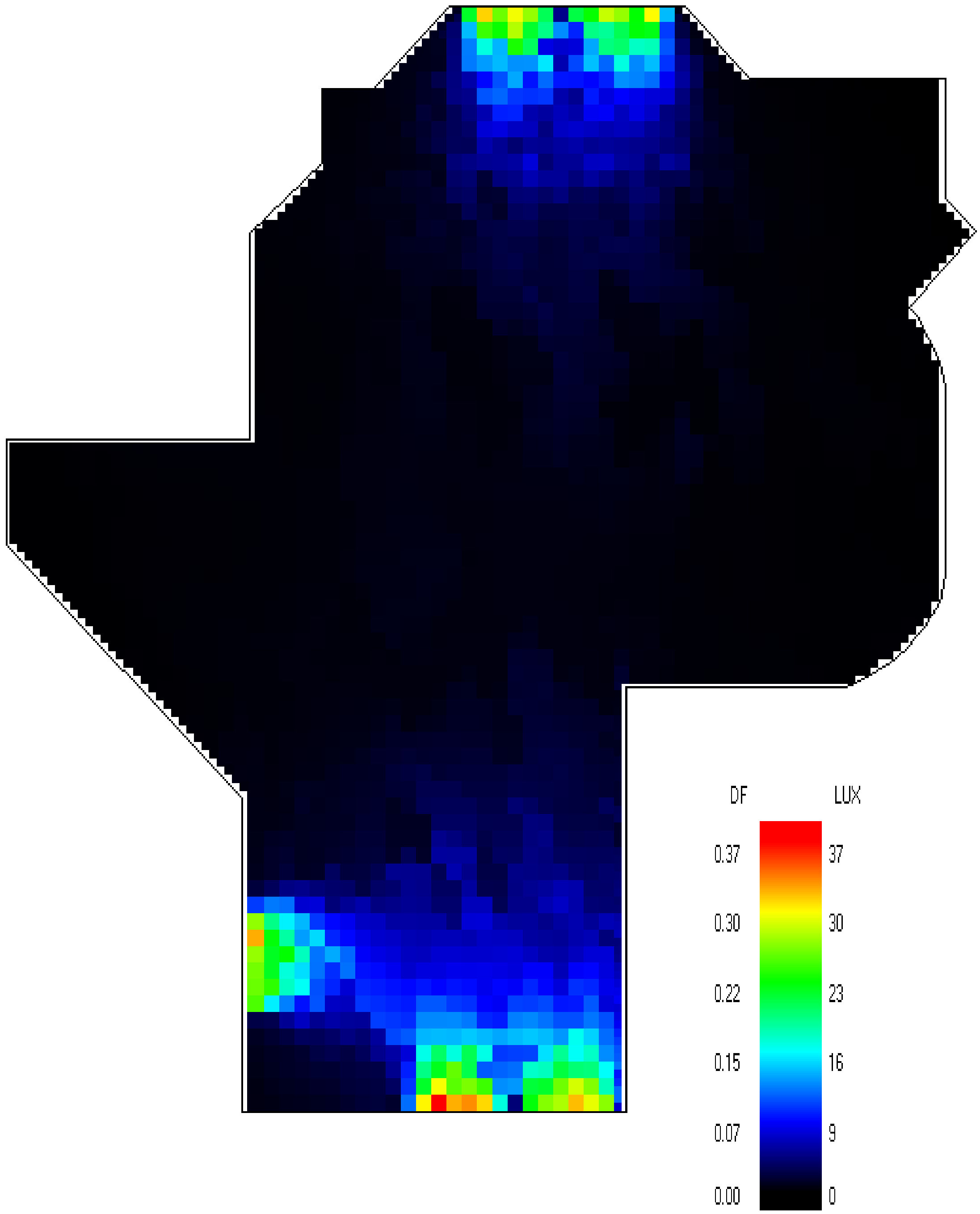


Figure 7-17 Gypsum mashrabiya design 1 living area daylight

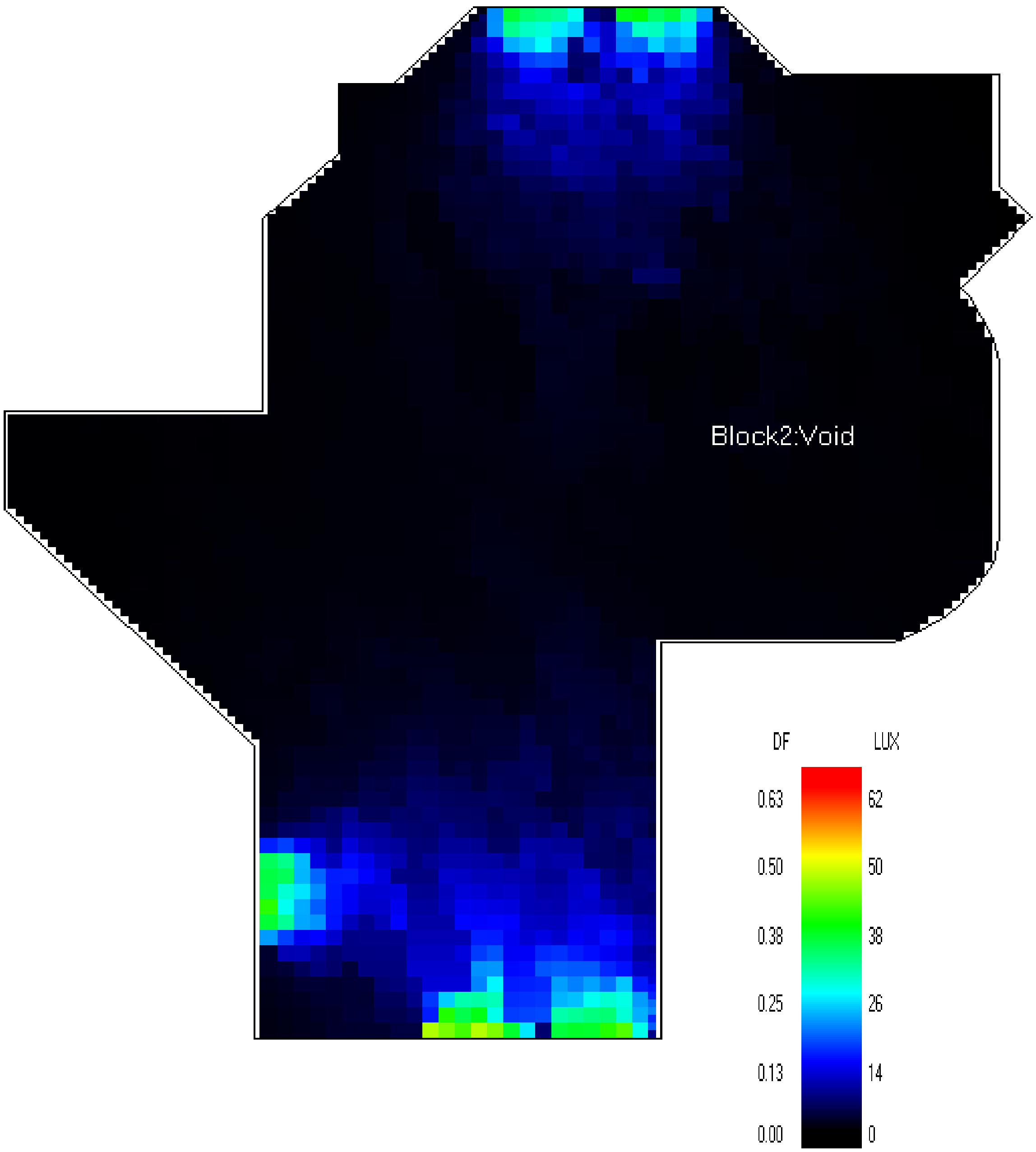


Figure 7-18 Gypsum mashrabiya design 2 living area daylight

The four images fig (7-19), fig (7-20), fig (7-21) and fig (7-22) show natural lighting, lack of privacy and the impact of mashrabiya on both. Fig (7-19) shows the amount of glare on the far left in the interior while the far right reveals how residents use curtains to prevent the glare. Fig (7- 20) shows the use of blackout in the interior.

Figure 7- 19 Actual daylight in villa case study with window treatment

Figure 7- 20 Actual daylight in villa case study with window treatment

Fig (7-21) the image is an outcome after the use of 3D Max drawing for the base case for the living room without window treatment. It is clear that without window treatment there is no privacy. Fig (7-22) the image shows how using mashrabiya provides not only privacy but also prevents the glare leaving the light patterns for decorations.

Figure 7- 21 3D max drawing for the actual daylight in living room with double glazed window

Figure 7- 22 3D max drawing for the actual daylight in living room with gypsum mashrabiya

The figure (7-23) below of the villa from design builder shows the reflection of the distribution of the daylight factor on the floor filtered through the mashrabiya design.

Figure 7-23 Daylight reflection Gypsum mashrabiya D2

7.2.2 Indoor Operative Temperature without AC (Natural Ventilation)

Table 7.4 Design Builder input for simulation operative temperature

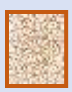
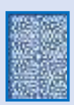
Glass window					**Outdoor air tempera-ture**
Type	**Opened/Closed**	**Curtain Open/Closed**	**Solar transmission value**	**Air change rate**	**The monthly average**
Double glazed windows with wooden and Gypsum mashrabiya both design 1 small holes and design 2 large holes	the double-glazed window is 50% opened for both mashrabiya design 1 with small holes and 2 with large holes.	Fully opened	For Wood 0.780 For Gypsum 0.700	3 (AHR)	between November and March

Below is the statistical data reflecting the indoor operative temperature with natural ventilation, that is, when the AC is switched off and the double-glazed window is opened 50% wide for the period from November to March when the outside temperature is reasonably comfortable according to the ASHRAE standards, that is, between 20 to 27^{0}C. In relation to indoor operative temperature with natural ventilation, *mashrabiya* design 2 with large holes are effective with an average of 27.11 ^{0}C than designs with small holes 27.29^{0}C due to air regulation, whereby large holes allow more air into the interior.

The fact that gypsum material is porous enables heat to be transferred through conduction, convection, and radiation through the pores. In addition, due to this porosity water vapour can escape from gypsum in less time than wood, hence promoting the cooling of the indoor environment. On the other hand, wooden *mashrabiya* design 2 is not as effective as gypsum due to its poor water vapour resistivity.

***Mashrabiya* material have more effect on the indoor temperature then the design.**

Table 7- 5 Indoor operative temperature without AC (natural ventilation)

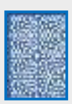
		Jan	Feb	Mar	Nov	Dec
outside dry bulb temp (°c)		22.79	23.57	25.04	26.87	25.05
	Existing building 'double glazing window'	27.72	28.74	30.22	32.41	30.21
	Wooden *mashrabiya* design 1	27.62	28.63	30.22	32.53	30.18
	Wooden *mashrabiya* design 2	27.39	28.41	30.01	32.46	30.02
	Gypsum *mashrabiya* design 1	27.29	28.36	29.96	32.16	29.82
	Gypsum *mashrabiya* design 2	27.11	28.13	29.67	31.86	29.57

7.3 Villa Simulation Result with AC

7.3.1 Indoor Operative Temperature with AC

The diagram below shows the results on the impact of wooden and gypsum mashrabiya with small and large holes (design 1 and 2) on operative temperature with air conditioning system on with a fixed set point of 16^{o}C and set back at 20^{o}C. According to the results wooden mashrabiya design 1 is lower in operative temperature than design 2 and this is similar when material is changed showing that the use of gypsum mashrabiya design 1 reduces operative temperature. In terms of the highest and lowest, wooden and gypsum mashrabiya design 1 are lower in operative temperature than design two in both materials. The table shows August with the higher operative temperature of 28.13^{0}C and 28.12^{0}C for wooden and gypsum mashrabiya design 2 than April with figures as low as 26.31^{0}C and 26.34^{0}C, respectively. The recordings in operative temperatures follow the same pattern of the design and material as above where August is higher, and April is lower showing the figures of 27.33^{0}C and 27.76^{0}C and 25,46^{0}C and 25.19^{0}C correspondingly. The simulations stages included where the AC was on, and off which shows differences in the outcomes indicating the impact of design and material.

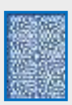
Table 7- 6 The indoor operative temperature with AC between April and October

		Apr	May	Jun	Jul	Aug	Sep	Oct
outside dry bulb temp (°c)		**27.63**	**30.57**	**31.01**	**33.16**	**33.13**	**31.13**	**29.87**
	**Existing building 'double glazing window'**	**26.46**	**27.30**	**27.55**	**28.14**	**28.25**	**27.83**	**27.24**
	**Wooden *mashrabiya* design 1**	**25.46**	**26.31**	**26.58**	**27.18**	**27.33**	**26.83**	**26.14**
	**Wooden *mashrabiya* design 2**	**26.31**	**27.15**	**27.41**	**27.99**	**28.13**	**27.66**	**26.99**
	**Gypsum *mashrabiya* design 1**	**25.90**	**26.75**	**27.02**	**27.60**	**27.76**	**27.28**	**26.59**
	**Gypsum *mashrabiya* design 2**	**26.34**	**27.20**	**27.44**	**28.03**	**28.12**	**27.67**	**27.05**

7.3.2 Solar Gains Exterior Windows

The table (7-7) below represents simulation for solar gains in exterior windows calculated in kilowatt hours having added wooden and gypsum *mashrabiya* large and small hole design in the base case villa with double glazed windows. According to the simulation results wooden mashrabiya design 1(with small holes) has lower solar gain than design 2 (with large holes) recording figures of 930 and 1380 kWh, respectively. On the other hand, gypsum mashrabiya design 1 is lower in solar gain than design 2 the results show 60 and 1360 kWh correspondingly. Overall gypsum mashrabiya design one has the lowest solar gain which means that it is the most efficient in providing a cool indoor environmental quality'. The impact of solar gain seems to depend on the design of the *mashrabiya* and the material they are fabricated from. For example, the difference between wooden *mashrabiya* design 1 and design 2 is 450 kWh, where design 2 is the highest of the two. In relation to the fabrication material, the difference between wooden and gypsum *mashrabiya* designs 1, was 870 kWh, with gypsum being the lowest and most effective.

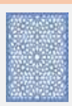
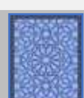
Table 7- 7 Solar gains from exterior windows

		Annual solar gain	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
outside dry bulb temp (°c)			22.79	23.59	25.04	27.63	30.57	31.01	33.16	33.13	31.13	29.87	26.87	26.05
	**Existing building 'double glazing window'**	**3 320**	**290.23**	**280.15**	**279.01**	**258.60**	**317.48**	**312.57**	**299.50**	**245.69**	**260.79**	**255.39**	**259.03**	**258.08**
	**Wooden *mashrabiya* design 1**	**930**	**61.65**	**67.25**	**81.59**	**67.36**	**90.59**	**87.26**	**86.86**	**82.97**	**79.83**	**79.03**	**70.00**	**62.05**
	**Wooden *mashrabiya* design 2**	**1 380**	**109.53**	**102.98**	**117.21**	**115.17**	**121.66**	**120.98**	**119.24**	**112.38**	**114.34**	**116.34**	**113.54**	**114.68**
	**Gypsum *mashrabiya* design 1**	**60**	**3.58**	**3.94**	**4.82**	**5.21**	**5.43**	**5.24**	**5.22**	**4.92**	**4.74**	**4.67**	**4.10**	**3.60**
	**Gypsum *mashrabiya* design 2**	**1 360**	**106.06**	**101.07**	**116.21**	**114.57**	**121.32**	**120.62**	**118.84**	**111.87**	**113.05**	**115.83**	**110.58**	**110.03**

7.3.3 Cooling Load

The table (7-8) below shows the simulation results for the energy consumed for cooling the interior environment using wooden and gypsum mashrabiya design 1 and 2 added to the base case villa with double glazed windows in the summer period between April and October. The results showed that the use of wooden *mashrabiya* design 2 uses less energy for cooling compared to design 1 by 2 160 kWh. After changing the material to gypsum, mashrabiya design 2 showed a further reduction of 3 421 kWh compared to design 1 in the usage of energy for cooling. (For 7 months)

Table 7- 8 The annual total energy usage for cooling the existing villa, and with wooden and gypsum.

Total energy usage for mechanical cooling of the indoor environment for the months from April to October		
	**Existing building 'double glazing window'**	**42,154 kWh**
	**Wooden *mashrabiya* design 1**	**35,853 kWh**
	**Wooden *mashrabiya* design 2**	**33,692 kWh**
	**Gypsum *mashrabiya* design 1**	**31,470 kWh**
	**Gypsum *mashrabiya* design 2**	**28,049 kWh**

7.3.4 Total Energy Consumption

The table (7-9) below shows the simulation results for the total energy consumed annually by the base case villa with double glazed windows after the addition of wooden and gypsum mashrabiya design 1 and 2. The results show that the villa case study with wooden *mashrabiya* design 1 and 2 recorded a figure of (97,91 kWh and 101,539 kWh) respectively. After the second simulation process, the results showed that wooden *mashrabiya* design 1 is more effective than design 2 by 3,629 kWh, a difference <u>of 3.6%.</u> The two designs were further simulated with the gypsum material, the results for which showed a further decrease in total energy usage but where design 2, with large holes, proved to be better than design 1 by a difference of 1,416 kWh, <u>or 1.5%.</u> The results below indicate that the material used to fabricate the *mashrabiya* plays a major role in the amount of energy consumed.

Table 7- 9 The annual total energy consumption in all cases

Annual Total Energy consumption		**kWh**
	**Existing building 'double glazed window'**	**106,114**
	**Wooden *mashrabiya* design 1**	**97,910**
	**Wooden *mashrabiya* design 2**	**101,539**
	**Gypsum *mashrabiya* design 1**	**95,531**
	**Gypsum *mashrabiya* design 2**	**94,115**

7.4 Comparison of simulation results between the existing base case villa with double glazed windows and case study villa with double glazed widows with added gypsum mashrabiya design 1 and 2

7.4.1 Simulation using Natural Ventilation.

<u>*7.4.1.1 Daylight Factor*</u>

Table 7- 10 Comparison of simulation results between double glazed windows and with added mashrabiya in existing case study villa

Stages	Factors	Base Case villa with double glazed windows	Base case villa with double glazed windows with added gypsum mashrabiya design 1	Base case villa with double glazed windows with added gypsum mashrabiya design 2	The changes in %
Natural ventilation (without air condition)	Daylight factor	1.58 LUX	0.60LUX	0.66LUX	
	Operative temperature	$29.86^{0}C$	$29.52^{0}C$	$29.27^{0}C$	2%
Air condition	Artificial light	51. 302 kWh			
	Operative temperature	27,54 ^{0}C	26.99 ^{0}C	27.41 ^{0}C	2%
	Solar gain	3320 kWh	60 kWh	1360 kWh	98%
	Cooling load	42 155 kWh	31 470 kWh	28 049 kWh	33%
	Total energy consumed	106 114 kWh	95531 kWh	94 115 kWh	11%

The table (7-10) above is a comparison of the simulation results on the factors that impact on energy usage in a base case villa with double glazed windows. These results are then compared to the base case villa with double glazed windows including gypsum *mashrabiya* design 1 and 2. In the first stage, daylight factor and operative temperature were simulated with natural ventilation. The results show that the daylight in the base case villa with double glazed windows is 1.58 LUX. which within the acceptable standard mentioned by BREEAM 1.5 LUX. According to the observations it was clear that the residents are not utilising the day light factor because of the use of window treatment to prevent the glare and provide privacy which cannot be ignored within the Saudi culture intertwined with religion. The results show that even though mashrabiya has lower daylight factor below the acceptable standard, it can provide not only privacy but also filter the natural lighting and remove the glare. The issue of low daylight factor in mashrabiya can be resolved by increasing the size of windows and mashrabiya holes ensuring effective diffusing of daylight. For example, adjustments can be made to the design of the *mashrabiya*, particularly the louvers, ensuring they can be moved to regulate the amount of light so as to be appropriate for the comfort of the residents.

Table 7-11 A particular day in august comparison of simulation results between double glazed windows and with added mashrabiya in existing case study villa

	Existing villa base case	Wooden mashrabiya D1	Wooden mashrabiya D2	Gypsum mashrabiya D1 With small holes	Gypsum mashrabiya D2 with large holes	The difference between existing villa base case and with gypsum mashrabiya D1
Operative temperature	28.35	26,99	27.79	26.35	27.82	7%
Solar gain	6.50	2.90	3.87	2.00	3.37	69%
Cooling load	120.45	152.69	149.34	88.97	142.42	26%
Total energy	307.40	300	302.20	156.35	288.77	49%

The table (7-11) indicates the simulation results of operative temperature, solar gain, cooling load and total energy for existing villa, and the addition of wooden and gypsum mashrabiya design 1 and 2 on a particular day in august when the outside average temperature read 32.67 ^{0}c and the ac set point was 16^{0}c and set back was20^{0}c according to data from observations. The results clearly indicate that gypsum mashrabiya design 1 is more effective. In comparison to the base case, the difference in percentage for the operative temperature, solar gain, cooling load and total energy is 7, 69. 26 and 49% respectively.

The difference in annual operative temperature between existing villa base case and with mashrabiya design 1 (small holes) is 2%. However, comparison of the difference in daily operative temperature is 7%. Overall, the simulation results for operative temperature are very low annually whereas the daily figures are higher.

7.4.1.2 Operative Temperature

The second factor in the first stage of simulation with natural ventilation shows comparison of operative temperature in the base case villa with double glazed windows 50% wide opened with added gypsum mashrabiya design 1 with small holes and design 2 with large holes. The simulation process was carried out between November and March when the outdoor temperature was within the acceptable range. The results indicate that overall, the use of gypsum *mashrabiya* design 1 and 2 are effective in the reduction of indoor operative temperature when used with double glazed windows although design 2 is more effective than 1. It should be noted that the outdoor average temperature of 24.66^{o}C is within the acceptable range while the indoor temperature of 29.52^{o}C and 29.27^{o}C using both designs is uncomfortable temperature however, this can be solved by enlarging the sizes of the windows and enlarging mashrabiya holes for all the existing buildings. If the sizes of the holes are larger, then the cooling and humidification rate is also increased. In addition, building orientation should be considered, especially in the new buildings. Overall, it can therefore be concluded that adding gypsum *mashrabiya* to the base case villa reduces the indoor operative temperature using natural ventilation.

7.4.2 Simulation Using Air Conditioning

7.4.2.1 Operative Temperature with Air Condition

The results above show the comparison of indoor average operative temperature from April to October when the air condition is turned on between the base case villa with double glazed windows and with added gypsum mashrabiya design 1 and 2. It is clear that the addition of gypsum mashrabiya design 1 and 2 to the base case villa is more effective in reducing indoor operative temperature however, design 1 is even more effective than design 2. The difference in indoor operative temperature between the base case villa and the addition of gypsum mashrabiya design 1 is 0.55^{o}C which is 2%. This clearly shows that using gypsum mashrabiya promotes indoor environmental quality.

7.4.2.2 Solar Gain

The results show the differences in solar gain between the base case villa with double glazed windows and with addition of gypsum mashrabiya design 1 and 2. According to the results there is a reduction in both design 1 and 2 however, design 1 has a significant difference in the amount of solar gain between the existing building and mashrabiya design 1 recording a figure of 98 %. The results show how the design has an impact on solar gain hence the small holes recorded a total of 60 while the large holes have 1 360 which shows the amount of heat gained through the holes. There is also a relationship between solar gain and indoor operative temperature in relation to the mashrabiya design which is reflected in the fact that design 1 with small holes reflects heat gain and results in comfortable indoor environmental quality. It can be concluded that the lower the solar gain the more comfortable the indoor environmental quality.

7.4.2.3 Cooling Load

The table 7-8 represents the total energy used for cooling indoor environment between April and October. According to the results gypsum mashrabiya design 2 is more effective with the total cooling energy usage of 28 049 kWh compared to the base case villa with the highest figure of 42 154 kWh a significant difference of 14 105 kWh and a figure of 33%.

7.4.2.4 Total Energy Consumed

The simulation results in relation to the total energy consumed annually for cooling, lighting and use of appliances in a base case villa compared to the villa with added gypsum mashrabiya design 2 showed total energy usage of **94 115** kWh compared to the base case villa with the highest figure of **106 114** kWh a significant difference of **11 999** kWh a figure of **11 %**. The results indicate that adding gypsum material in mashrabiya produces far better results, however, the results obtained when comparing designs (small and large holes) proved to be inconsistent.

7.5 Conclusion

Overall, it can be concluded that the simulations indicate that *mashrabiya* fabricated from a gypsum material would be the most effective across all the parameters investigated which include cooling, indoor operative temperature with AC and solar gain, as well as natural lighting and ventilation, all of which affect energy consumption. Simulations suggest that, of those designs tested, *mashrabiya* design 2 (with large holes) would be the most effective in the reduction of energy consumption, particularly with regard to indoor operative temperature with natural ventilation, cooling, daylight and total energy usage. On the other hand, *mashrabiya* design 1 with small holes seemed to be efficient in relation to indoor operative temperature with AC and could allow for a significant reduction in solar gain compared to the existing villa with double glazed windows.

CHAPTER EIGHT

8. Discussion and Conclusion

8.1 Discussion

The discussion of this research is divisible into four areas including architectural identity, residents' privacy, energy consumption, and mashrabiya. The section on mashrabiya is derived from the main topic in order to address the impact of mashrabiya as a result the section addresses all the elements regarding mashrabiya including the history up to its abandonment to highlight how this has had an impact on energy performance in residential buildings which is another section. In addition, identity and privacy are also considered as separate sections mainly to address the social cultural aspect of the objectives. Therefore, all the responses from online questionnaire, interviews from the specialists and Albasateen residents as well as measurements taken during field study together with observations and dynamic thermal simulation have addressed the four area of research.

8.2 Architectural Identity 'Hejazi architecture'

There are several factors that are considered in any society which define its architectural identity. The western part of Saudi Arabia has significant features or architectural elements that resemble or identify its architectural history and identity such as *mashrabiya*. The information on the investigation regarding the architectural identity in Jeddah was analysed from the data provided during the interviews by two government organisations including Jeddah Municipality and the Saudi Commission for Tourism and National Heritage. The other set of data was collected from the online questionnaire and Albasateen residents through interviews.

According to the results above on which element is considered the most significant in relation to architectural identity, 100% of the respondents from Jeddah Municipality and the Saudi Commission for Tourism and National Heritage highlighted *mashrabiya* as the most important architectural element reflecting Hejazi architecture. In addition to the identity of the city, the same government organisations unanimously agreed that contemporary residential buildings fail to reflect Hejazi identity. The majority of responses, totalling up to 90% from the Albasateen residents' interviews, also show that contemporary residential buildings do not reflect Hejazi architectural identity. It is clear from the above results that Jeddah has lost its architectural identity and *mashrabiya* are identified as a key factor and element which demonstrate Hejazi architectural identity.

Figure 8- 1 Influence of western style architecture (Source: Google Maps 2019).

It can be clearly seen from fig (8-1) and (8-2) above that Jeddah has shifted from its traditional architecture to resemble multiculturalism. Both pictures above show a sloping roof adapted from snowy and rainy climatic regions which is not relevant to Jeddah's hot and dry climate. (See 3.4.2 Climate conditions)

Figure 8- 2 Buildings showing lack of privacy and identity (Source: Google Maps 2019).

The buildings above are foreign in that the design, finishing material, land planning and gaps between neighbours do not consider the society in terms of its culture and traditions. Fig (8-1) is a true reflection of the residents' responses to lack of identity.

While architectural identity has been lost in the city of Jeddah, *mashrabiya* are mentioned as being the most significant Hejazi architectural element that could restore the architectural identity of the City. Jeddah Municipality, the Saudi Commission for Tourism and National Heritage and Albasateen residents are of the opinion that if *mashrabiya* are reinstated this would restore the architectural identity of the city.

8.3 Residents' Privacy

Although privacy can be simply defined in general, it has different cultural meanings which vary depending on the various factors of the community in question. The definition of privacy varies from country to country and within religions, even though this may be diverse as well. An example can be seen in the level of privacy within the same religion between Egyptians and Saudis where Saudis have a distinct separation between genders, Egyptians maintain separation though with minimal restriction. The information analysed to address the question of privacy was taken from 261 online responses and 48 Albasateen District residents.

In response to the question on the level of privacy from online questionnaire, 94% of the residents claimed to have privacy in their homes. However, only 6% stated that there is lack of privacy. Although the respondents claimed to have privacy, it is interesting to note that 100% use some form of protection to provide privacy in their homes such as curtains, shutters, blackouts, trees, and tall fences. This clearly indicates that there is, effectively a total lack of privacy otherwise. In addition, the responses from the Albasateen District residents show that 75% have no privacy while 25% claim to have privacy. The online questionnaire and Albasateen residents' interview responses show a significant difference because of the research methods used, the interviews and observations, which meant that residents had to be honest in the responses. Even though a small percentage still claimed to have privacy, the observations reflect a lack of privacy due to the types of window treatment stated above. It can therefore be concluded that there is no privacy in contemporary residential buildings.

One of the factors which contributed to lack of privacy is the abandonment of *mashrabiya*, introduction of AC, and adoption of the glass window. Not only did the glass window prove to be ineffective due to lack of privacy, but it also contributed to other issues including the glare from sunshine and solar gain through the glass window resulting in interior thermal discomfort. In order to solve the issue of privacy, glare and heat gain, residents opted for window treatment such as curtains, shutters, blackouts, trees, and tall fences. The solution to the problem of privacy, glare and heat gain caused other problems with regard to darkness and high interior temperatures. This led to the residents using artificial light during the day and night as well as air conditioning in seeking indoor environmental quality. This is the reason why residents consume more energy.

The shift from Hejazi traditional architecture, which is identified by its most significant architectural element, the *mashrabiya*, to contemporary architecture which adapted the use of the glass window resulted in lack of privacy in Jeddah residential buildings. Many other issues beside privacy developed from the use of glass window of which *mashrabiya* would solve these issues if reinstated.

8.4 Energy Consumption

According to literature review, one of the reasons for conducting this research is based on the relative lack of study of the continuous rise in energy consumption in Saudi Arabia. The results from the Saudi Electricity Company specialists' interviews indicate that the increase in energy consumption in Saudi Arabia is still an issue, hence they state that they are dissatisfied with the current reduction of energy consumption. It should be noted that SEC is the organisation that provides electricity to residential buildings; hence this department is aware of the typical energy usage for each household. The results from the case study villa on the comparison of energy consumed before and after the increase in tariffs show that there is a slight reduction in energy consumption of around 3%, yet the cost is significantly higher than before, with a total increase of 84%. This is one of the reasons SEC is dissatisfied with the overall reduction in energy consumption.

The results represented above from the case study villa before and after the increase in electricity tariffs are substantially high, while in terms of energy consumption are slightly low. This indicates that the results from the online questionnaire and Albasateen residents' interviews 69 and 83% respectively would be unacceptable after the change in tariffs, based on their satisfaction with their annual electricity bills. Another example of the online responses was that approximately 50% of residents indicated their dissatisfaction with the cost of their electricity bills, which ranged from 5000 to 15,000 SR annually, indicating a higher usage of electricity before the increase. However, after the increase in tariffs, the residents will pay from 9,150 to 27,450 SR, which is an 83% increase based on the figures from the original case study villa.

One of the reasons for high electricity costs is likely to be the continuous usage of air conditioning in the winter when the outdoor temperature is mostly comfortable, and the 24-hour usage of air conditioning during other seasons. In support of the above, the online questionnaire results show that 26% of the respondents use air conditioning in winter, while 100% claimed to use it during other seasons. The outcomes from the Albasateen resident interviews showed a total of 79% used air conditioning in winter, whilst 100% used it during the other three seasons. On the daily usage of air conditioning, 44% of online respondents admitted to using air conditioning for between 6 and 24 hours per day. The Albasateen residents' results for the same questions indicate that 58% of respondents used their air conditioning from 6 to 24 hours, the behaviour of occupants has an impact on energy consumption. According to the online questionnaire and Albasateen residents' interview results for the question about the type of AC and its operation times, the residents use AC most of the time, which indicates higher levels of energy consumption.

Additionally, the average outside temperature taken from Design Builder in January is 23^{o}C, while the set point, as recorded in the villa case study by the researcher in the living room was 21°C, which is low considering the outdoor temperature is around 33°C in winter in the afternoons, the season when the interview was carried out. The temperatures in the evening drop to around 20°C, and hence residents do not require 21°C as a set point. As recommended by the Saudi Energy Efficiency Centre (SEEC) (2017), the acceptable set point for indoor environmental quality is in the range of 23°C - 25°C, although the results from the Albasateen District residents set the air conditioning (AC) lower than 22°C.

While there are many factors that have been investigated, in relation to energy consumption the building information such as the area of the building, the age, the number of floors, and orientation have proven to also contribute to the continuous rise in energy consumption. The number of occupants in this villa is six, which increases the use of energy. Finally, the construction material also plays a vital role in increased or reduced energy consumption. In this situation, the villa case study was insulated in 2006, even though the Government regulation in this regard came into existence in 2010, reflecting the importance the resident placed on indoor environmental quality. It can be concluded from the results above that this case study villa consumes more energy than might otherwise be required due to factors such as the building information, number of occupants, type of AC, set point, as well as operation times and the use of large glass windows and also construction material details, and hence the increased rates of payment as shown by the figures of 98,847 kW/h and 10,193 SR, respectively, for the resident's electricity account.

On the same question, Jeddah Municipality, who are responsible for the approval of building plans, are hesitant to confirm that the energy consumed has reduced of late as this is not part of the responsibilities and specialty of the organisation. However, in rating the building materials which contribute to energy increase, Jeddah Municipality's architects emphasised orientation and the size of the building as two of the factors that have an impact on energy consumption, noting the fact that a southern orientation is the worst to adopt in the city of Jeddah. In support of the above, the Saudi electricity Company and Saudi Energy Efficiency Centre highlighted orientation as having a major impact on energy usage. In rating the building envelope in terms of which element contributes to the greatest increase in energy consumption, not all of them rated the building envelope although the roof was rated the highest followed by the exterior walls and finally the windows.

The results from the 48 residents in Albasateen District show that 56% of the villas have north, northeast, northwest, north east west and north east south orientations, which have a positive impact on energy consumption, although it should be noted that the northern orientation is the most effective one in Jeddah, as represented by 20%. In contrast, 44% of the residents' homes have a south, east and west orientation which contributes negatively to energy performance. If the façade is southerly oriented, additional heat is absorbed from the sun due to its longer period of exposure. This will result in residents using more air conditioning to cool the interior environment, which suggests the 44% of the residents in the research would be forced to use air conditioning. The facades facing the northern part are not exposed to the sun, and hence show no heat gain, which is effective and has no direct impact on energy consumption except for the exterior temperatures. Even if the government organisation architects claim that orientation has a major impact on the use of energy, not all the villa facades are poorly orientated and the building planning in the city allows other villas to act as shading devices by blocking the sun.

On the other hand, the Saudi Energy Efficiency Centre (SEEC) reports that energy consumption is under control, although there is still more to be done. This outcome is based on the plans related to energy reduction, such as importing quality appliances that will eventually reduce energy usage. The Saudi Energy efficiency centre (SEEC) also provides workshops to increase awareness amongst residents with regard to the energy efficiency standards and regulations for products such as air conditioning and other appliances. Based on the research objectives on which operational systems consume additional energy, the interviewees from the SEEC and SEC both 100% identified air conditioning as the highest contributor to energy consumption, followed by appliances, with lighting being the lowest. The SEEC standards are confirmed by the results for the villa case study where the resident reduced energy consumption by 3%, which could have been as a result of the replacement of the air conditioning with the quality unit approved by the SEEC.

However, Jeddah Municipality agreed that air conditioning led to the largest consumption of power but considered lighting to be the second largest. This is supported by the observational and simulation results, where the researcher found that all the residents contacted used artificial lighting during the day due to the widespread use of curtains, blackouts, and shutters to promote privacy. Moreover, the extreme use of artificial light in the daytime due to the use of shading devices as residents attempt to limit glare from sunshine results in an increase in energy consumption.

When the Albasateen District residents revealed the importance of and gave their personal assessments in rating the factors that impact indoor environmental quality, there was a considerable contrast between answers. For example, they rated natural lighting and ventilation as very important (indeed, most, and second-most important), while in evaluating their homes the residents rated the natural lighting and ventilation as the two least factors, indicating limited natural lighting and ventilation. On the other hand, the results showed artificial lighting and ventilation as relatively unimportant, whilst in assessing their homes they rated them the first two factors, which suggests what they value the most they do not actually experience in their homes.

The energy consumption simulation in Design Builder showed the effectiveness of gypsum *mashrabiya* design 2 in reducing energy consumption (from 106,114 kWh to 94,115 kWh). The results from the Saudi Energy Efficiency Centre interviews show how *mashrabiya* have the potential to and reduce energy consumption from their shading effect, which has been shown by the simulations to reduce energy usage. Changing the material from wood to gypsum resulted in a significant difference, indicating that gypsum is more effective than wood in reducing energy consumption.

It is clear that residents would prefer the use of natural lighting and ventilation in their homes, which in turn would reduce the consumption of energy. However, artificial lighting and ventilation are mostly used. The reason why residents choose artificial lighting is due to the use of window shading devices, leaving the residents without natural lighting. The use of *mashrabiya* would solve this issue for residents, allowing them to benefit from its functions, including allowing natural lighting and ventilation.

8.5 Mashrabiya

Mashrabiya play an important role in this research as they are an intended solution to its objectives in relation to the reduction of energy consumption in a hot climate, restoration of Hejazi architectural identity, and to provide privacy for the residents in the western region of Saudi Arabia.

According to the architect's interviews, 100% of the respondents stated that they were aware of *mashrabiya* and their functions, although only 37% knew all the functions. These architects believe that *mashrabiya* should be reinstated to restore the Hejazi architectural identity of the city of Jeddah, as well as to reduce energy consumption as a shading device. The simulations indicate that *mashrabiya* can reduce energy consumption in residential buildings, as shown by the total energy reduction from 106,114 kWh to 94,115 kWh, or about 12%, justifying the fact that they should be reinstated although consideration is needed regarding the responses from the residents. In the process of enhancing identity and reducing energy consumption, it is assumed that the privacy for residents would naturally be achieved. In reinstating *mashrabiya*, the architects suggest the change of material to gypsum or palm leaf stem for sustainability purposes since wood is not locally produced and is expensive. According to the simulations, gypsum material has the potential to reduce energy usage even further, hence its usage is highly likely to reduce energy consumption.

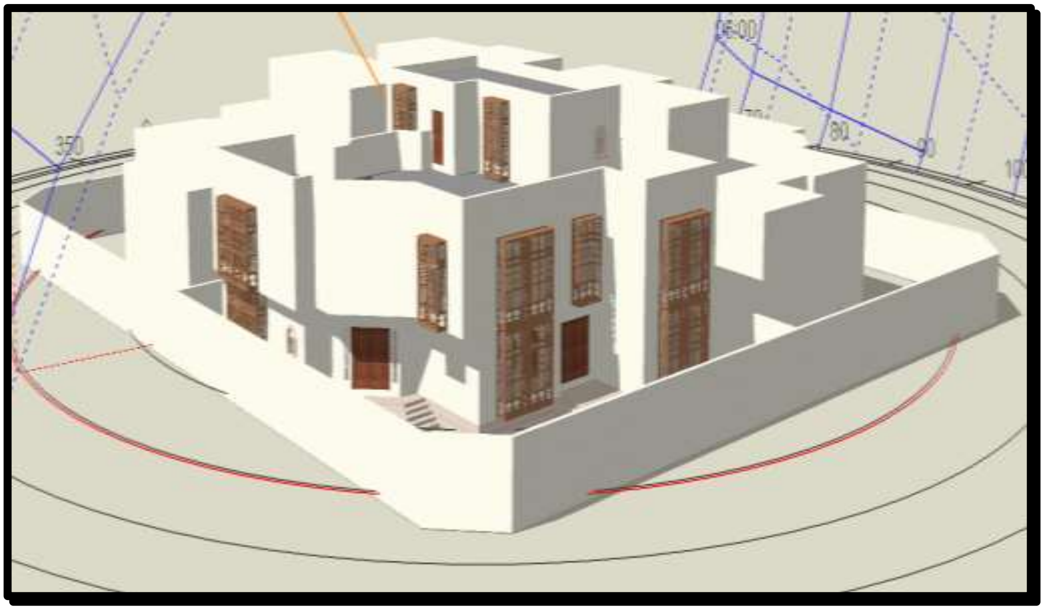


Figure 8- 3 Villa case study with wooden mashrabiya D2

Most of the 261 responses to the online questionnaire and 48 interviews from Albasateen indicate the respondents to not only have knowledge of *mashrabiya* but also their functions. Although these functions, as highlighted by the residents, have the possibility to reduce energy usage if used in residential buildings, only 4% of the online responses claimed they use *mashrabiya*, but none of whom were resident in Albasateen. One of the most valued aspects in Saudi culture is privacy, and the online questionnaire and Albasateen results indicate that 55% and 33%, respectively, of the responses indicate that *mashrabiya* were felt to provide privacy. This shows the significance of *mashrabiya* as an architectural element that, if reinstated, will not only solve the problem of reducing energy consumption but also those of enhancing privacy and identity.

On the question of why residents did not use *mashrabiya* having noted their value, they identified the fact that they are old fashioned, not easily available on the market, and in any case expensive. Since the results regarding *mashrabiya* show that they can reduce energy consumption, enhance architectural identity, and provide privacy in residential buildings, the responses from the online questionnaire and Albasateen District interviews show the high demand for reinstating *mashrabiya*. However, it should be noted that there are a number of issues that need to be considered before reinstating *mashrabiya*, as suggested by residents. One of these recommendations include changing the design of *mashrabiya* from their traditional style, which is both complicated and detailed and collects dusts and makes them difficult to clean. The residents suggest a change of material from wood to one which is easy to clean and colourful. Another suggestion is the reduction of the cost of *mashrabiya*. The reason why traditional *mashrabiya* are expensive is because of the wood, which is not locally manufactured and has a complicated design that requires handmade carvings. The residents stated that this can only be achieved by simplifying the *mashrabiya* design and changing the material to one that is locally produced, and which is environmentally friendly, easy to shape, clean and coloured. It should be noted that a simplified design for *mashrabiya* with gypsum material was used in Design Builder simulations which suggested an associated reduction in energy usage and which, if reinstated, will also provide privacy and enhance architectural identity.

Figure 8- 4 Villa case study with white gypsum mashrabiya D1

Having discussed the aspects of *mashrabiya* such as the functions which include natural ventilation, lighting, cooling, privacy, and reduction of structural load, the results confirm that *mashrabiya* has an impact on residential buildings in terms of energy performance, and further can enhance the traditional architectural identity in Hejazi region and provide the privacy for residents which is fundamental to Saudi society. The design for the *mashrabiya* has been shown to be valuable as residents suggested a simplified version, although the simulations show that a large size design would reduce energy usage more in residential buildings. While the functions and design play an important role in the modified *mashrabiya*, the material is also important in reducing energy consumption as residents indicated a preference for the change from traditional wooden *mashrabiya*. As a result, the researcher has chosen to simulate gypsum in Design Builder for the model of the modified *mashrabiya*. It can therefore be concluded that the modified *mashrabiya* are not only the ideal architectural element but are also a significant architectural element that can be used in residential buildings to not only reduce energy consumption but also provide identity and privacy.

Figure 8- 5 Case study villa with colourful gypsum mashrabiya

8.6 Summary of the research findings

Objective 1• Identify which *common architectural and operational systems affect energy consumption levels in residential buildings in the context of Jeddah in Saudi Arabia.*

The results from the four government interviews indicate the roof to be the highest contributor to energy consumption followed by the exterior walls and windows although the architects' results indicate orientation to be the most important feature in relation to energy consumption. According to the Saudi Energy Efficiency Centre (SEEC), the U-value for roof is actually less than that of the walls, which indicates that roofs contribute more to energy consumption than walls. The literature review indicates that heat loss and gain is through windows, walls, roofs, and doors, and which hence have an impact on energy consumption.

The fact that the specialists selected the roof as the highest in contributor to energy consumption is due to the periods of their exposure to sunshine. Their basis on orientation being the most important aspect in energy consumption is contradictory as the roof will have no effect given a particular orientation, but which may differ according to orientation.

In terms of operational systems, it is clear that SEEC, SEC and JM rate air condition as the highest contributor to energy consumption followed by appliances stated by SEEC and SEC. It is interesting that JM rated lighting as the second contributor to energy usage which is also echoed by the observational results from 48 villas from Albasateen District where residents used artificial lighting even in the daytime. In addition, the villa case study simulation results showed that lighting is the second highest contributor to energy consumption. Finally, JM rated appliances as the lowest contributor to energy consumption while these were rated the second by the SEEC and SEC.

Conclusions can be drawn that air condition and artificial lighting contribute more to the increase in energy usage in residential buildings in Jeddah. Using mashrabiya and its functions which include natural ventilation and lighting with double glazed windows in residential buildings is highly likely to minimise the usage of air condition and artificial lighting.

Objective 2• *Examine the privacy and social cultural needs of residents in privately owned buildings in Jeddah.*

Having investigated the level of privacy through 261 online questionnaire and 48 interviews from the residents in Albasateen district. The results indicated that there is no privacy although 82% of the online respondents claim to have sufficient privacy as well as 75% responses from Albasateen district however, they still use window treatments such as curtains, blackouts, and shutters to enhance privacy, which in itself is indicative of lack of privacy as also confirmed in the literature review.

On the other hand, the results from 8 specialists' interviews, 261 online responses from residents, as well as the interviews with 48 Albasateen District residents, all showed that residents feel architectural identity in Jeddah has diminished resulting in buildings not reflecting Hejazi architecture. In addition, the loss of identity is attributed to the abandonment of mashrabiya which is the most significant architectural element in Hejazi architecture. Globalisation, modernisation, and westernisation are highlighted as main reasons to the loss of architectural identity in Jeddah. The discussion above clearly shows that the contemporary residential buildings in Jeddah do not reflect Hejazi architectural identity and the lack privacy. Therefore, using mashrabiya in contemporary residential buildings will restore Hejazi identity and also provide privacy for residents due to its design which allows residents to see the outside world without being seen.

Objective 3 Investigate *the effect of mashrabiya on the level of privacy and identity for residential buildings in Jeddah.*

According to the responses from 261 online questionnaire and 48 interviews regarding privacy, the majority of the residents stated that *mashrabiya* can provide privacy in residential buildings while on the question of architectural identity the architects from the Saudi Commission and National Heritage are convinced that if *mashrabiya* are reinstated they will provide privacy and enhance identity. Mashrabiya is designed in such a way that the privacy of residents within a building is invisible to the outside world enabling the residents to view and benefit from the nature. *Mashrabiya* is associated with Hejazi architecture and therefore the absence of *it* will automatically mean the loss of identity hence it is regarded the most significant element of Hejazi architecture. According to the results, the residents would prefer re-instating of *mashrabiya* however, with simple design, affordable price, and different material except wood. In the discussion *mashrabiya* is not only required by residents it is also ideal in increasing the level of privacy as well as enhancing the Hejazi architectural identity in residential buildings in Jeddah city.

Objective 4. *Assess the energy performance for an existing case study villa using the Dynamic Thermal Simulation Tool.*

Design Builder was used to simulate the existing case study villa with double glazed windows with and without air conditioning for calibration purposes to ensure that the results obtained from simulation are accurate when compared to the real case study villa electricity account. According to the simulation results of the existing case study villa the total energy consumed showed to be close to the existing villa with only a difference of 7 267 kWh.

The aim for the simulation included an assessment of the operative temperature and daylight with natural ventilation while operative temperature, cooling demand, and artificial light as well as solar gain and total energy consumption were simulated with air condition. The difference in total energy shows that the results for the simulation can be viewed as authentic and valid.

Objective 5 Evaluate *the impact of mashrabiya facade on indoor environmental quality and energy consumption as applied to the case study villa in item 4.*

The objectives were achieved through the simulation which included the case study villa with wooden *mashrabiya* design 1 and 2 with and without air conditioning, after which the material was changed to gypsum to simulate the same designs 1 and 2, to assess the operative temperature and daylight with natural ventilation whereas operative temperature, cooling demand, and artificial light including solar gain and total energy consumption were simulated with air condition turned on. Both designs appeared to be effective with regard to the same parameters; gypsum *mashrabiya* design 1 was found to produce an improved operative temperature and solar gain while gypsum *mashrabiya* design 2 was the most effective in terms of cooling, daylight, and total energy consumption. It can be concluded that the difference in operative temperature between gypsum *mashrabiya* design 1 and 2 is when the air conditioning is on, and hence overall gypsum mashrabiya design 2 is the more effective in the reduction of energy consumption.

According to the results for objective 5, gypsum *mashrabiya* design 2 was identified as the most effective architectural element, which the simulations show reduces energy consumption, enhances natural ventilation, improves indoor cooling, and provides natural lighting as well as reducing total energy consumption. The results above confirm the functions of *mashrabiya* as listed in the study context in chapter 2.

It can therefore be concluded that re-instating gypsum mashrabiya particularly design 2, in residential buildings, will not only reduce energy consumption but it will also provide residents' privacy and enhance Hejazi architectural identity in Jeddah city.

8.7 Research Impact

- In response to whether *mashrabiya* have an impact in residential buildings in terms of energy performance and social cultural aspects, it can be concluded that the use of gypsum *mashrabiya* in residential buildings can potentially lower energy usage by a significant amount, as shown by the Design Builder simulation program.
- Using gypsum *mashrabiya* in buildings façades will reduce the continuous increase of energy consumption in hot climate countries.
- The results indicate that adding gypsum mashrabiya design 2 on villa façades showed the reduction in annual total energy consumption with a significant difference of **11 %**.

- *Mashrabiya* will also raise awareness on energy performance in residential buildings, which can contribute to the reduction of electricity bills there by saving money.
- *Mashrabiya* will also improve indoor environmental quality while promoting the reduction of Co2 emission.
- *Mashrabiya* will allow residents to benefit from natural lighting and ventilation.
- *Mashrabiya* will improve indoor air quality promoting individual wellbeing.
- In addition, gypsum *mashrabiya* will also restore and enhance the Hejazi architectural identity of the city of Jeddah as well as provide privacy for residents which is an especially important aspect in Saudi culture.
- *Mashrabiya* can be added to existing buildings as well as future developments.
- Gypsum *mashrabiya* have been modified to the needs of the resident such as affordability, a change in material, as well as a simplified design.
- The results of the research, investigated through both the quantitative and qualitative approaches, simulations, and support from the literature review, all point to the fact that *mashrabiya* have the potential to at least be part of the solution for addressing the continuous increase in energy consumption in Saudi Arabia, particularly Jeddah.
- The robustness of the methodological approach in the built environment could be considered as one of the research outcomes.

<u>New knowledge</u>

- Literature reviews show that buildings in Saudi Arabia lost not only architectural identity but also the resident's privacy because of the adoption of western style particularly large glass windows which has resulted in poor indoor environmental quality leading to excessive use of AC contributing to continuous increase in energy consumption.

- Re-instating *mashrabiya* to residential building in hot climate countries (Jeddah) will reduce energy consumption and enhance the Hejazi architectural identity and provide privacy to the residents.
- *Mashrabiya* material and design has an impact on indoor environmental quality see section 8.6 Summary of the research findings, objective 5.

8.8 Future Work and Recommendations

GOVERNMENT

- The government should sponsor researchers to investigate the impacts of size and orientation of in residential buildings through simulation.
- To enhance identity Jeddah municipality should ensure that government policies are applied to promote uniformity in residential building facades.
- The government should lead by example by using on their buildings.
- The Saudi Housing Ministry is in the process of building about 1.5 million homes, which represents an excellent opportunity for the government to employ and that people will copy.

GYPSUM MANUFACTURERS

- Gypsum manufacturing companies should produce gypsum which is treated so that it is suitable for use in the local climate and easy to clean.

DESIGNERS

- Designers should produce a variety of simple designs which meet the needs of the residents for the market.
- One of the factors that have been discovered and should be considered for further research is the differences on the result for the designs.

FUTURE WORK

- Several areas of research developed during the process however, due to time constraints further investigations would not be possible.
- In the event of availability of time, it would have been ideal to investigate the impact of orientation in relation to energy performance in a case study villa.
- Another area of focus could have been the impact of surrounding buildings on energy performance, day light and natural ventilation.
- It would have been interesting to investigate the impact of the number of facades on energy performance in buildings.
- Another area of research would have included the simulation of the villa case study with led lighting instead halogen and florescent to find out the differences in energy usage.
- The implementation of modified mashrabiya on a real villa then calculate actual measurements (total energy consumption, cooling load, operative temperature and natural lighting and ventilation).

References and bibliography

ABDEL-GAWAD, A. (2012) Veiling Architecture: Decoration of Domestic Buildings in Upper Egypt 1672-1950. The American University in Cairo Press. The American University in Cairo Press.

ABDELRAHMAN, M., SAID, S. and AHMAD, A. (1993) A comparison of energy consumption and cost-effectiveness of four masonry materials in Saudi Arabia. Energy, 18 (11), pp. 1181-1186.

ABU-GHAZZEH, T.M. (1997) Vernacular architecture education in the Islamic society of Saudi Arabia: Towards the development of an authentic contemporary built environment. Habitat International, VOL 21 (2), pp. 229-253.

ACHARI, P, D. (2014) Research Methodology: A guide to ongoing research scholars in management. London: Horizon Books.

ADAS, A.A. (2013) Wooden Bay Window (Rowshan) Conservation in Saudi-Hejazi Heritage Buildings. ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, (2), pp. 7-11.

AJAJ, A. and PUGNALONI, F. (2014) Re-thinking traditional arab architecture: a traditional approach to contemporary living. International Journal of Engineering and Technology, 6 (4), pp. 286.

AKBAR, S. (2012) The Diminishing Role of Windows from Traditional to Modern. Newcastle, England: Newcastle University.

AKBARI, H., MORSY, M. and AL-BAHARNA, N. (1996) Electricity Savings Potentials in the Residential Sector of Bahrain. vol. 1 Lawrence Berkeley National Laboratory Publication p. 11–20

AKSAMIJA, A. (2015) High-Performance Building Envelopes: Design Methods for Energy-Efficient Facades. In: Proceedings of the Building Enclosure Science and Technology (BEST) 4 Conference.

AKSAMIJA, A. (2016) Design methods for sustainable, high-performance building facades Adv Build Energy Res, 10 (2) pp. 240-262

ALAIDROOS, A. and KRARTI, M. (2015) Optimal design of residential building envelope systems in the Kingdom of Saudi Arabia. Energy and Buildings, 86, pp. 104-117.

ALANZI, A., SEO, D. & KRARTI, M., (2009) Impact of building shape on thermal performance of office buildings in Kuwait. Energy Conversion and Management, 50(3), pp.822– 828.

AL-ATTIYAH, A. (2015) Reversing the trend in domestic energy consumption in the GCC http://www.thegulfintelligence.com/uploads/Publications/Industry%20Report.pdf

AL-BAN, A. Z. G. (2016) No title. Architecture and Cultural Identity in the Traditional Homes of Jeddah, roshans) in the old city of Jeddah (Saudi Arabia) u sing image-based techniques. ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., II-5/W1. XXIV International CIPA Symposium, pp. 7-12.

ALDAWOUD, A. (2013) Conventional fixed shading devices in comparison to an electrochromic glazing system in hot, dry climate. Energy and Buildings, 59, pp. 104-110.

ALDOSSARY, N.A., REZGUI, Y. and KWAN, A. (2014) Domestic energy consumption patterns in a hot and humid climate: A multiple-case study analysis. Applied Energy, 114, pp. 353-365.

ALENAZY, T. (2007) The privacy and social needs of women in contemporary Kuwaiti home. Unpublished thesis (MA.), Florida State University.

AL-GHAMDI SA, ALSHAIBANI KA (2017) The potential of solar energy in Saudi Arabia: the residential sector. J Eng Arch 5(2):32–53 ALITANY, A. (2014) A New strategy of ICT integrated methodologies for 3D documentation. Ph.D. thesis: UNIVERSITY POLITECNICA DE CATALUNYA.

AL-HATHLOUL, S. (1981) Tradition continuity and change in the physical environment the Arab-Muslim city. Dissertation, MIT, Department of Architecture, pp. 160–166.

ALITANY, A., REDONDO, E., ADAS, A., (2013) The 3D Documentation of Projected Wooden Windows (The Roshans) in the Old City of Jeddah (Saudi Arabia) Using Image-based Techniques.

AL-JAMEA, M. (2014) Towards social and cultural sustainability in the designs of contemporary Saudi houses. Int J Sustain Hum Dev, 2 (1), pp. 35-43.

ALJOFI, E. (2005) The potentiality of reflected sunlight through Rawshan screens. In: Proceedings from the International Conference “Passive and Low Energy Cooling for the Built Environment”. Santorini, Greece.

ALLARD, F. (1998) Natural, Ventilation in Building: A Design Handbook. London: The Cromwell Press.

AL-LYALY, S.M.Z., (1990) The traditional house of Jeddah: a study of the interaction between climate, form and living patterns. University of Edinburgh.

ALMURAHHEM, F. (2008) Behind the Roshan: Visualising the Roshan as an architectural experience in traditional domestic interiors. Published thesis (PhD.), University of Brighton. AL-NAIM, M.A. (2008) Identity in transitional context: open-ended local architecture in Saudi Arabia. International Journal of Architectural Research, 2 (2), pp. 125-146.

ALMURAHHEM, F.M. (2011) The nineteenth century western travelers’ conception of the harim: restoring the cultural complexity of the Hijab in Architecture, Islamic architecture 1 (4), pp.167-180.

ALNASER N. (2009) Utilisation of Solar and Wind Energy in Buildings in the Kingdom of Bahrain: A Step towards Sustainable Building Construction. Unpublished thesis (PhD.), University of Reading.

ALOTHMAN, H. (2017) An Evaluative and Critical Study of in Contemporary Architecture. Master Thesis, Near East University, North Cyprus.

ALRASHED, F. and ASIF, M. (2015) Climatic Classifications of Saudi Arabia for Building Energy Modelling. Energy Procedia, 75, pp. 1425-1430.

AL-SAADI, S. and BUDAIWI, I. (2007) Performance-based envelope design for residential buildings in hot climates. In: Proc. Building Simulation: Citeseer, pp. 1726-1733.

AL-SANEA, S.A. (2002) Thermal performance of building roof elements. Building and Environment, 37 (7), pp. 665-675.

AL-SANEA, S.A. and ZEDAN, M. (2011) Improving thermal performance of building walls by optimizing insulation layer distribution and thickness for same thermal mass. Applied Energy, 88 (9), pp. 3113-3124.

AL-SANEA, S.A., ZEDAN, M. and AL-HUSSAIN, S. (2012) Effect of thermal mass on performance of insulated building walls and the concept of energy savings potential. Applied Energy, 89 (1), pp. 430-442.

AL-SANEA, S.A., ZEDAN, M. and AL-HUSSAIN, S. (2013) Effect of masonry material and surface absorptivity on critical thermal mass in insulated building walls. Applied Energy, 102, pp. 1063-1070.

AL-SHAREEF, F. (1996) Natural light control in Hejazi architecture: an investigation of the Rowshan performance by computer simulation. Unpublished thesis (PhD.), Liverpool University.

AL-SHEHRI, A. (2008) Electricity industry in Saudi Arabia: an overview. In: Saudi water and power forum, Jeddah.

ANDERSEN, R.V. et al. (2009) Survey of occupant behaviour and control of indoor environment in Danish dwellings. Energy and Buildings, 41 (1), pp. 11-16.

ASHRAE (1997) Handbook: Fundamentals. Atlanta, GA: American Society of Heating, Ventilating and Air-Conditioning Engineers.

ASHRAE (2008) ASHRAE/ASHE Standard: Ventilation of Health Care Facilities – ANSI/ASHRAE/ASHE Standard 170-2008. ISSN 1041-2336. American Society for Heating, Refrigeration and Air-conditioning Engineers, Atlanta, Georgia.

ASHRAE Guide, (1966) ASHRAE Guide and Data Book Applications for 1966 and 1967 American Society of Heating, Refrigerating and Air Conditioning Engineers, Atlanta, GA.

ASHRAE, (1992) ANSI/ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy, Atlanta: American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc., USA.

ASHRAE, (2004) ANSI/ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, Atlanta: American Society of Heating, Refrigerating, and Air-conditioning Engineers, Inc., USA.

ASHRAF, N., AL-MAZIAD, F., (2014) Effects of facade on the energy performance of Education Building in Saudi Arabia (PDF Download Available). Presented at the World Sustainable Building, Barcelona, Spain

ASHRAF, S., (1983). Elrawashin of Jeddah, Saudi Arabia, cit. Jannas, S. Passive and low energy architecture, Oxford, Pergaman press.

BAHAMMAM, A. (1998) Factors that affect the size of contemporary dwelling in Saudi Arabia. Habitat International, Vol. 22, no. 4, pp. 557-570.

BAHGAT, G. (2013) Alternative Energy in the Middle East: Springer.

BAKER, S.E., EDWARDS, R. and DOIDGE, M. (2012) How many qualitative interviews is enough: Expert voices and early career reflections on sampling and cases in qualitative research.

BATTACHRYYA, D.K (2006) Research methods 2nd New Delhi: Anurag Jan for Excel books.

BATTERJEE, S.A. (2010) Performance of Shading Device Inspired by Traditional Hejazi Houses in Jeddah Saudi Arabia.

BEN-HAMOUCHE, M. (2013) Complexity of urban fabric in traditional Muslim cities: Importing old wisdom to present cities. Urban Design International, 14 (1), pp. 22-35.

BERGER, P. L. AND LUCKMAN, T. (1967) The Social Construction of Reality. London: Early Bird Books.

BLOM, I., ITARD, L. and MEIJER, A. (2011) Environmental impact of building-related and user-related energy consumption in dwellings. Building and Environment, 46 (8), pp. 1657-1669.

BOKHARI, A. (1978) Jeddah, a study in urban formation. University of Pennsylvania,

BREBBIA, C.A. AND CLARK, C. (2014) Defence Sites 11 Heritage and Future. London: witPress.

BRINKMANN, S and Kvale (2007) Doing Interviews, London: SAGE

BRYMAN, A. (2008) Social research methods. 3rd ed. Oxford: Oxford university press.

BRYMAN, A. (2012) Social Research Methods New York: Oxford University Press Inc

BRYMAN, A. (2016) Social research methods. 5th ed. Oxford: Oxford university press.

BYNUN, R.R. (2001) Insulation. USA: McGraw Hill.

CASTILLO-CAGIGAL, M., GUTIÉRREZ, A., MONASTERIO-HUELIN, F., CAAMAÑO-MARTÍN, E., MASAB, J.D. JIMÉNEZ-LEUBE, J. (2011) A semi- distributed electric demand-side management system with PV generation for self-consumption enhancement. Energy Conversion and Management Volume 52, Issue 7, July 2011, Pages 2659-2666

COHEN, L, MANION, L, AND MORRISON, K. (2000) Research Methods in education 5th edn.

COHEN, L., MANION, L. and MORRISON, K. (2013) Research methods in education: Routledge.

CONSTANZA, R. and DALY, H. E. (1992) Natural capital and sustainable development. Conservation Biology, 6 (1), pp 37-46.

CONSUELO, ET AL (1992) Research Methods. Philippines: Quezon city Rex Printing company

CRESWELL J.W. (2007) Qualitative inquiry and Research Design: choosing among five approaches. London: Sage.

CRESWELL J.W. (2015) 30 Essential Skills for the Qualitative Researcher SAGE publications, Los Angeles.

CRESWELL, J.W (2005). Educational research. Planning and conducting evaluating Qualitative and Quantitative research: London: Pearson.

CRESWELL, J.W. (1998) 5th edn. Qualitative inquiry and Research Design: choosing among five approaches. London: Sage.

CRESWELL, J.W. AND CRESWELL, J.D. (2017) 5th edn. Research Design: Qualitative and Quantitative and Mixed Methods approaches.

CRESWELL, J.W. PLANO C, CATHMAN V.L. AND HANSON E.E. (2003) advanced mixed methods research design in TASHAKKORI, A. AND TEDDILIE, L.C., Handbook of mixed methods in social and behavioural research pp 209-240. CA: Thousand Oaks Sage:

CRESWELL, J.W., AND CLARK V.L.P. (2018) Designing and conducting Mixed Methods Research. London: Sage.

CZAJA, R. AND BLAIR (2005) Designing Surveys: A Guide to decisions and Procedures. London: Pine Forge Press.

CZAJA, R. AND BLAIR, J. (2005) Designing surveys: a guide to Discussions and Procedures. London: Pine Forge Press.

DANE, F. C (2011) Evaluating Research: Methodology for People who Need to Research London: Sage

DANESHPOUR, A (2011) Concept of Privacy in housing design based on Islamic teachings. IN Proceedings of the First Iranian.

DASGUPTA, P. and SERAGELDIN, i. EDS (2000) Social capital: A Multifaceted Perspective. Washington DC: World Bank.

DAVIS, J. P., EISENHARDT, K. M., & BINGHAM, C. B. (2007) Developing theory through simulation methods. Academy of Management Review, 32(2), 480-499.

DE DEAR, R. (2004) Indoor environmental quality' in practice. Indoor Air, 14 (s7), pp. 32-39.

DE GROOT, EM, PEIKMAN, S AND OPSTELTEN I (2008) Dutch research into user behaviour in relation to energy use of residence proceedings. PLEA Conferences

DESCOMBE, M. (2017) The Good Research guide for small scale social research projects. McGraw Hill: Open University.

education: Fundamental Elements and Issues 2edn.: Lippincott Williams and Wilkins

ELSHORBAGY, A. (2010) Traditional Islamic-Arab House: Vocabulary and Syntax, International Journal of Civil & Environmental Engineering IJCEE- IJENS, 10(04), pp. 15-20.

ELZEN, B., GEELS, F. W., & GREEN, K. (2004). System innovation and the transition to sustainability: Theory, evidence, and policy Edward Elgar Publishing.

FANGER, P. O. (1967) Calculation of indoor environmental quality' : Introduction of a basic comfort equation. ASHRAE Transactions, 73(2), III4.1-III4.20.

FEENEY, J. (1974) The magic of. Saudi Aramco World, 25 (4).

FELIMBAN, A.; PRIETO, A.; KNAACK, U.; KLEIN, T.; QAffAS, Y. Assessment of Current Energy Consumption in Residential Buildings in Jeddah, Saudi Arabia. Buildings 2019, 9, 163.

FETHI, H. (1986) Natural Energy and Vernacular Architecture. United Nations University, Tokyo, Japan, 65, pp. 84.

FLICK, U. (2006) An introduction to Qualitative Research. London: The Sage

FLICK, U. (2018) Handbook of Qualitative Research. London: The Sage

GAGGE, A. P. BURTON, A. C. AND BAZZETT H. C. (1941) a Practical System of Units for the description of the heat exchange of man with his thermal environment. Science NY. 94 428-430.

GAY, L. R. GEOFFRY, E. M. PETER, A. (2009) Educational research: Competencies for analysis and Application. London: Pearson; 366-37ia

GIVONI, B. (1994) Passive and Low Energy Cooling of Buildings. New York: John Wirely & Sons

GLASER BG AND STRAUSS (1967) the discovery of grounded theory: Strategies for qualitative research: Chicago: aldine.

GÖÇEK, G. (2011) The Transformation of Turkey: Redefining State and Society from the Ottoman Empire to the Modern Era. London, England: I.B. Tauris & Co Ltd.

GOFFMAN, E. (1959) The Presentation of Self in Everyday Life. New York: Double Day

GREELY, K. HURRIS, J AND HATCHER, A. (1990) Measured Energy Savings and Cost Effectiveness of Conversation Retrofit in Commercial Buildings Proceeding of the ACEEE (1990) summer Study on energy efficiency in Building.

GREENE, JC (2007) Mixed Methods in social inquiry. Jersey: Wiley

GUERRERO, H. (2000) Excel Data Analysis: Modelling and Simulation. London: Springer

HAAS, R.H. AUER, H. AND BIERMAYR, P. (1998) The impact of Consumer Behaviour on residential Energy Demand for space heating, energy Buildings. 27pp 195-205

HAGUE, R. (2006) Unlocking the design potential of rapid manufacturing. Rapid manufacturing: an industrial revolution for the digital age. West Sussex: John Wiley and Sons.

HAKIM, B. and AHMED, Z. (2006) Rules for the Built Environment in 19th Century Northern Nigeria. Journal of Architecture and Planning Research, 23(1), pp.1- 26.

HAKIM, B.S. (1986) Arab- Islamic cities: Building and planning principles. New York: KPI.

HALL, C. CLEVELAND, C. KAUFMANN, R. (1986) Energy and Resource Quality: The Ecology of the Economic Process. U.S.A. Wiley, New York.

HARIRI, M. (1991). Design of Rowshan and its importance to the Dwelling. In Journal of Umm Al-Qura University, Third year, Issue 5 (1411 H) (1992), Makkah, Saudi Arabia, pp.175-237, p. 177.

HARIRI, M. (1992) Design of Rowshan and its importance to the dwelling. Journal of the Umm-Al-Qura University, 3 (5), pp. 175-237.

HART, C. (2005) Doing your masters dissertation: Sage.

HERKEL,S., KNAPP,U. and PFAFFEROTT, J. (2008) Towards a model of user behavior regarding the manual control of windows in office buildings : Building and Environment, Vol 43 (4) , pp. 588-600

HOJJATOLLAH, R.K. (2012) Identity Discourse in Islamic Architecture. Department of architecture, Faculty of Engineering, University of Mohaghegh Ardabili, Ardabil, Iran, Journal of Basic and Applied Scientific Research, 2 (1), pp. 926-934.

http://www.NCL.eblib.com/EBLWeb/patron?target=patron&extendedid=P_431524_ 0&.

ISO (1984) 7730 Moderate Thermal Environments - Determination of the PMV and PPD indices and specification of the conditions for indoor environmental quality' , 1stedition, International Standards Organization, Geneva, Switzerland.

JANSSON ET AL (1994) Investing in Natural Capital: The Ecological Economics Approach To sustainability. USA: Island Press

JOHNSON, D. G. (2000) Population, food, Knowledge: American Economic. Review. Vol 90 no. 1 pp 1-14. Kaizer, T. (1984) Shelter in Saudi Arabia., London: Academy Editions.

KAMAL, A. (2014) The morphology of traditional architecture of Jeddah: climatic design and environmental sustainability. Gber, 9, pp. 4-26.

KAMAL, M.A., (2011) The Study of Thermal Mass as a Passive Design Technique for Building Comfort and Energy Efficiency., 5(1), pp.84–88.

KAMALSKI D.M, VERDAASDONK R.M, DE BOORDER T, VINCENT R, VERSNEL H, GROLMAN W. (2014) Comparing mechanical effects and sound production of K.T.P, thulium, and CO2 laser in stapedotomy. Otol Neurotol. 2014;35(7):1156-1162.

KARAJ, T. (2013) Architectural energy efficiency: Berlin: Univesitsverlag. der

KENZARI, B. and ELSHESHTAWY, Y. (2003) The ambiguous veil: On transparency, the Mashrabiy'ya, and architecture. Journal of Architectural Education, 56 (4), pp. 17-25.
KHAN, S. (1986) Jeddah Old Houses, Saudi Arabia: King Abdulaziz City for Science and Technology.

KHATIB, JM sustainable construction of materials 2edn (2016) London: Woodhead publishing

KIBERT CJC (2013) sustainable construction: green Building design and delivery; framework for sustainable construction in 1994 CBT

KING, G., 1998. The traditional architecture of Saudi Arabia. London: I.B. Tauris publishers.

KLANDERMANS, B ET AL (2000) Social Movement Research. London: University of Minnesota Press.

KOENIGSBERGER, 0., INGRESOLL, T., MAYHEW, A. AND SZOKOLAY, S. (1977) Manual of Tropical Housing. Part One: Climatic Design, London: Longman Group Ltd.

KOTHARI, C.R (2004) Research methodology: methods of Techniques New Delhi: New Age international The New Delhi: the energy resources institute.

KOTHARI, C.R. (2004) Research Methodology Methods and Techniques. New Age International Pvt. Ltd., Publishers, Available at:

KRISHNASWAMY, K. N., SIVAKUMAR, A. L. AND MATHIRAJAN, M. (2006) Management of research Methodology: Integration of Principles, Methods and Techniques. India: Pearson education.

Kumar, P. (2019) Role of CFD in evaluating occupant indoor environmental quality' : the simulation Hub.

KUMAR, R. (2019) Research methodology: a step-by-step guide for beginners. 4th ed. London: Saga publications.

KVALE, S. (2007) Doing Interviews: The Sage Qualitative Research Kit. London: SAGE Publication Ltd.

LINCOLN, LYNHAM AND GUBA (2011) in Jones, S. R., Torres, V and Arminio, J (2014) Negotiating complexities of Qualitative research in Higher.London: James & James.

MA, U (2011) No Waste; Managing Sustainability in Construction. Gower Publishing, Farnham (2011)

MAGALDI, I, N (2004) Sustainable design manual: Volume 2

MAGHRABI, A. (1995) Personal communication with local craftsman. leddah, Saudi Arabia.

MAGHRABI, A. (2000). Airflow Characteristics of Modulated Louvered Windows with Reference to The Rowshan of Jeddah, Saudi Arabia.

MANDALAKI, M. AND TSOUTSOS, T. Solar Shading Systems: Designs Performance and Integrated Phot Volaics. Greece: Springer.

MANI, M (1980) Handbook of Solar radiation in Yonnas, S. (1993) Passive and Low Energy Architecture. Oxford: Oxford University Press.

MASAUD, M. A. 1996. Adaptation and Motivation. Unpublished PhD dissertation, Edinburgh: Heriot Watt University, Edinburgh College of Art, December 1996.

MASOUD, K. G. (2014) Enhanced Phase Locked Loop Structures for Power and Energy Applications. Canada; IEEE Press

MASPERO, G. (1914). Manual of Egyptian Archaeology and Guide to the Study of Antiquities in Egypt. New York, NY: Putnams Sons Press

MCCLENNA, J (2004) sustainable design: the future of architecture Ecotone publishing Company

MCDONNELL, J., & O'NEILL, R. (2003). A Perspective on Single/Within Subject Research Methods and "Scientifically Based Research." Research and Practice for Persons with Severe Disabilities, 28(3). methodologies.

MOAN, J. L., & SMITH, Z. A. (2007). Energy use worldwide: A reference handbook ABC-CLIO.

MOHAMED, J. (2015). The Traditional Arts and Crafts of Turnery or.

MONETTE, D.R., SULLIVAN, T.J. and DEJONG, C.R. (2013) Applied social research: A tool for the human services: Cengage Learning.

MORTADA, H. (2003) Traditional Islamic principles of built environment: Routledge.

MOUJALLED, B., CANTIN, R. and GUARRACINO, G. (2008) Comparison of indoor environmental quality' algorithms in naturally ventilated office buildings. Energy and Buildings, 40 (12), pp. 2215-2223.

MTHISON (1988) IN HERRLITZ, W. ET AL (1994) Research on mother tongue education in comparative international perspective the oratival methodological issues. New York: Rodopi.

MURDAUGH (1999) IN STOMMEL, M AND WILLIS, CE Clinical research: concepts and Principles for advanced practice nurses (2004)

NAIM, M.A. (1998) Continuity and Change of Identity in the Home Environment Development of the Private House in Hofuf, Saudi Arabia. University of Newcas

NASROLLAHI (2012) Architectural Energy Efficiency: Berlin: Universitat Techische

NUMAN, M., ALMAZIAD, F. and AL-KHAJA, W. (1999) Architectural and urban design potentials for residential building energy saving in the Gulf region. Applied Energy, VOL. 64 (1), pp. 401-410.

O'NEILL, R. E., MCDONNELL, J. J., JENSON, W. R., BILLINGSLEY, F. F. (2002) (in preparation). Single case research designs: Applications in educational and community settings. Columbus, OH: Merrill.

OLATOYE, M. A. (2011) Basic concept in contemporary behavioural research methods. Lagos Nigeria. Meriworth; 100-114

OLIVEIRA, F. AND BITTENCOURT, L. S. (1998) "Air flow through louvered windows in small rooms". PLEA I

OPSTELTEN, I., GROOT, E. D., & SPIEKMAN, M. (2008). Dutch research into user behaviour in relation to energy use of residences. PLEA 2008-25th Conference on Passive and Low Energy Architecture, Dublin, Ireland, 22-24 October 2008., 5 P.

OTHMAN, Z., AIRD, R. AND BUYS, L. (2015) Privacy, modesty, hospitality, and the design of Muslim homes: A literature review. Frontiers of Architectural Research, 4 (1), pp. 12-23.

OUSALA, E. C. (1993) Introduction to research methodology. Onitsha Nigeria, African Publishers 118-142

PAPAKOSTAS K.T. AND SOTIROPOULES B.A. (1997) Occupational and Energy behaviour patterns in Greek residences. Energy and Building 26pp 207-

PARSONS, K.C. (1993.) 2nd Human Thermal Environment: The Effects of Hot, Moderate, and cold Temperature on Human Health, comfort, and Performance. London: Taylor Francis

PARSONS, K.C. (2003) Human Thermal Environment: The Effects of Hot, Moderate, and cold Temperature on Human Health, comfort, and Performance. New York: CRC Press

PASSERINI, G. C. (2018) WIT Transactions: The built Environment Vol 177: Islamic Heritage Architecture and Art 11. WIT Press: Boston.

PATRICK, S. R., PATRICK D.R., AND FARDO, S.W (1993) Factors affecting building construction. London: The Farmont Press.

PAUL G, DIETER A. (1993) Climate Responsive Building: Appropriate Building Construction in Tropical and Subtropical Regions: SKAT

PHILLIPS D.C. AND BURBULES N.C. (2000) Post positivism and educational and research. London: Sage

POLESE, M. and STEREN, R. (2000) The Social sustainability of cities: Diversity and Management of CHANGE: TORONTO: ON: UNIVERSITY OF TORONTO PRESS

PONTEROTTO, JG (2005) Qualitative research in Counselling Psychology: prima on research paradigms and philosophy of sciences. Journal of Counselling 52(126-128)

PRING, R. (2000) The ‘false dualism ‘of educational research. Journal of Philosophy of Education, 34 (2), pp. 247-260.

RABBAT, N. (2012) ED., The Courtyard House: From Cultural reference to Universal at Relevance. USA: Dept of architecture Massachusetts Institute of Technology.

RABBAT, N. (2012) What is Islamic Architecture anyway? Journal of Art Historiography, 6. pp. 115Radhi, H., & Sharples, S. (2013). Global warming implications of façade parameters: A life cycle assessment of residential buildings in Bahrain. Environmental Impact Assessment Review, 38, 99-108.

RAGETTE, F. (2012) Traditional Domestic Architecture of the Arab Region. UAE. American University of Sharjah.

RAGETTE, F., (2003) Traditional domestic architecture of the Arab Region. Edition Axel Menges.

RAPPORT, M. (1999) the Pacific Island: Environment and Society in ANU (1997) Outcomes and Implications NCDS. Hong Kong: Library of Congress Cataloguing.

REIS, H.T. and JUDD, C.M. (2000) Handbook of research methods in social and personality psychology: Cambridge University Press.

ROMANO, D., DE GROOT, D., GRAFAKAS, S., HEIN, L., NOCELLA, G., & TASSONE, V. (2008). Internet-based valuation and group valuation

ROSSMAN, G. AND WILSON, B. (1995) Numbers and Words? Combining Quantitative and Qualitative Methods in a single Large Scale. Evaluation Review (9) 627-643.

Royal Saudi Embassy, (2007) http://www.saudiembassy.or.jp/DiscoverSA/AR.htm Accessed 10th August 2018.

SACHS, I. (1999) Social sustainability and whole development: exploring the dimensions of sustainable development. In sustainability and social sciences a cross-Disciplinary approach to Integrating environmental Considerations Into theoretical Re-orientations, eds Becker, E. and Jahn, T. Paris, France: UNESCO Frankfurt am Main Germany: ISOE London.

SAID, S., & ABDELRAHMAN, M. (1989) Energy efficiency of a building in the eastern province of Saudi Arabia: Parametric analysis with DOE2. 1A. ASHRAE Transactions, 95, 147-152.

SAID, S., HABIB, M., & IQBAL, M. (2003) Database for building energy prediction in Saudi Arabia. Energy Conversion and Management, 44(1), 191-201.

SAINI, B.S. (1980) Building in Hot Dry Climates.: John Wiley and Sons.

SALEH, M.E. (1990) Impact of thermal insulation location on buildings in hot dry climates. Solar & Wind Technology, 7 (4), pp. 393-406.

SAMTMOURIS, M (2006) environmental Design of urban building an integrated approach London: Earch Scan

SANTIN, OG (2010) Actual energy consumption in dwelling: The effect of energy performance regulations and occupant behaviour. Netherlands: 105 press and the Imprint Delft University Press

SASSI, P (2006) Strategies for sustainable architecture USA: Taylor Pranase Library

School of Architecture and Urban Planning, University of Sheffield, Unpublished Ph.D. Thesis.

SCHWEIKER, M. and SHUKUYA, M. (2009) Comparison of theoretical and statistical models of air-conditioning-unit usage behaviour in a residential setting under Japanese climatic conditions. Building and Environment, 44 (10), pp. 2137-2149.

SHARMA, A. (2018) The cultinary Epic of Jeddah: The Tale of an Arabian Gateway.

SIDAWI, B. (2012) A Conceptual Analytic Model of the Vocabulary of the Islamic Architectural Heritage. Emirates Journal for Engineering Research, 17 (1), pp. 47-56.

SILVERMAN D (2000) Doing qualitative research London: SAGE.

SILVERMAN, D. (2003). Collecting and interpreting qualitative materials.

SLIFE B.D. AND WILLIAMS R.N. (1995) What is behind the Research: Discovering Hidden Assumptions in the behavioural sciences. London: Sage

SLOAN, P ET AL (2013) sustainability in the hospitality industry: Principles of sustainable operations 2nd edn. London: Routledge

SOBH, R, BELK, W. J WILSON A. J. (2013) Islamic Arab hospitality and multiculturalism Mark. Theory, 13 (4) (2013), pp. 443-463,

SOBH, R., BELK, R., (2011). Domains of privacy and hospitality in Arab Gulf homes. J. Islam. Mark. 2 (2), 125–137.

STEEMERS, K. AND YANNAS, S. Architecture and City Environment: Proceedings of PLEA (2000)

STOMMEL, M. AND WILLIS CE (2002) Clinical Research: Concepts and Principles for advanced Practice Nurse. #

STRANGE, T. AND BAILEY A (2008) sustainable development: linking economy society environment USA: OECD.

SUNG, W, KAO, JCM AND CLEN, R (2013) Environment energy and sustainable Development. London: CRC Press.

Szokolay, S. Introduction to architectural science: the basis of sustainable design, Architectural, Press/Elsevier, Oxford, UK (2004)

TALEB, H.M. (2011). Towards Sustainable Residential Buildings in the Kingdom of Saudi Arabia.

TARABULSY, M. (2008) Jeddah: City's Story. Al-Medina Printing and Publishing, Jeddah.

TAYLOR, J. K. and CIHON, C.C Statistical Techniques for Data Analysis. London: Chapman Hall CRC

TERI (The Energy and Resources institute) (2004) Sustainable Building: Design Manual. India: New Delhi.

THOMPSON, SK (2012) Sampling. Canada: A john: Wiley and sons' publication

THYER BA (2010) The Handbook of Social work of research Methods. 2edn London: Sage

UNESCO (2004) Historic Jeddah-the Gate of Makkah. Map of Inscribed Property.

UNESCO (2012) The Memory of the World in the Digital age: digitization and Preservation in TECTURAE in Arayici, Y. et al (2017) Heritage Building Information Modelling: Jeddah Heritage Building Information Modelling. (JHBIM) London: Routledge

UNESCO (2014) Historic Jeddah-the gate of Makkah. Map of Inscribed Property. Vision 2030. Saudi Arabia's Vision for 2030. 2016. Available online: https://vision2030.gov.sa/en/media-center (accessed on 15 September 2018).

VOGT, W.P. (2012) When to Use What Research Design. London: The Guilford Press.

VOGT, W.P., GARDNER, D.C. and HAEFFELE, L.M. (2012) When to use what research design: Guilford Press.

VOLK, L. (2015) The Middle East in the world: an introduction: Routledge.

WEI, S., BUSWELL, R. and LOVEDAY, D. (2013) Factors affecting 'end-of-day' window position in a non-air-conditioned office building: Energy and Buildings: .Vol 62, pp 87-96

WILEY J (2016) Qualitative Research Methods

WILLIAMSON, K. AND JOHANSON, G (2013) Research Methods, Systems Contexts. London: CP Chandos Publishing

WOOLLEY T (2013) Law Impact building: Housing renewable materials: London: Blackwell Publishing

YAKUBU, G.S. (1990) Modulated solar shielding of buildings: A study of solar radiation.

YAN, Y. Y. and Oliver, J. E. (1995) The clo: Utilitarian Unit to Measure Weather/Climate comfort. U.S.A: International Journal of climatology. Vol (16) pp 1045-1056.

YASSIN, A.A. and UTABERTA, N. (2012) Architecture in the Islamic Civilization: Muslim Building or Islamic Architecture. Journal of Islamic Architecture, 2 (2).

YIFAN LI (2018) THE SYNERGISTIC EFFECTS OF THERMAL ENVIRONMENT AND VISIBILITY UPON THE POPULARITY OF STREET RETAIL AREA. ----A CASE STUDY OF A RETAIL ARCADE IN GUANGZHOU. Georgia Institute of Technology.

YIN, R.K. (2018) Case study research and applications: design and methods. Sixth ed. Thousand Oaks, California: SAGE.

YIN, R. K. (2016) Qualitative research from start to finish. London: Guilford Press.

Appendix

Application to register for research degree.

Ethical approval

government Organization Letter

Government organization questionnaire

Al- Basateen resident’s interview questionnaire

Pilot Survey Results

Online Questionnaire Results

Simulation Results

Application to register for research degree.

Ethical approval

Application to Register for A Research Degree

DE MONTFORT
UNIVERSITY
LEICESTER

Mrs Shafiaa Saad Alghamdi
30 East Bond Street
Arcus
Flat 12
Leicester

LEI 4SX

3 April 2017

Dear Shafiaa,

Application to Register for A Research Degree

I am writing to inform you that following academic consideration it has been agreed that your application to register for the Doctoral Researcher Programme be approved.

You are now formally registered as a research student at De Montfort University.

Please also note your next progression milestone is the formal review report which was due to be submitted to the Graduate School Office by 01/02/2017.

Please complete the Formal Review: Student Form which can be located in your my Research record at https://myresearch.dmu.ac.uk. You will also find guidance notes within my Research which you may find helpful.

Upon successful completion of your formal review your registration for either MPhil or PhD will be confirmed.

If you require any further information, please do not hesitate to contact the Graduate School Office by email at researchstudents@dmu.ac.uk

Yours sincerely

Graduate School Office

Ethical approval

Faculty of Art, Design & Humanities Application to Gain Ethical Approval for Research Activities

For Official Use
Tracking No:
Date Approved:
Initials:

All research projects in the Faculty of Art, Design and Humanities (including applications to register for a research degree, final year undergraduate students undertaking a major project with research content, all post graduate degree students and all staff undertaking research projects) require approval from the Faculty Human Research Ethics Committee to ensure compliance with relevant UK laws, DMU regulations and best practice. To ensure compliance this form and any required supporting documentation (see overleaf) should be completed (in collaboration with the applicant's tutor if the applicant is a student) and submitted as a single PDF file to the Committee's servicing officer (see e-mail address below).

You will be advised of the outcome of your application once it has been considered. You must not undertake any research activity directly associated with those aspects of your research requiring ethical approval until you have been notified in writing that your application for them has been unconditionally approved by the Faculty Research Ethics Committee.

NOTE: ***If your research involves using 1) human tissue or fluid samples or 2) animals, you should seek guidance from the Chair of the Faculty Human Research Ethics Committee before planning the project.***

Please return this completed form to Faculty of Art, Design & Humanities Research Ethics Committee Servicing Officer at, CL0.08 ADHResearch&innovation@dmu.ac.uk

Section A: Applicant & Project Information

1. Applicant			
Last Name:	ALghamdi	First Name:	Shafiaa
DMU Email Address:	PI 5017159@my365.dmu.ac.uk		
School:	Architecture	Staff/Student	

2. Research activity for which ethical approval is being sought: Please state:

The Subject area and background:

I will need approval from the house owners for which I will be interviewing for my study.
I will make sure to obtain the required approvals and adhere to the ethical standards when publishing any materials about these houses... i.e. pictures or floor plans, audio recordings of the interview etc.

The aims and objectives:

The main aim of this research study is to determine the impact of mashrabiya on building energy performance and social cultural aspects in the hot climate of Jeddah, Saudi Arabia.

Objectives include:

1. Identify common architectural and operational systems that affect energy consumptions of residential buildings in the context of Jeddah, Saudi Arabia
2. Examine privacy and social/cultural needs of residents in privately owned buildings
3. Assess the energy performance of case study houses using Dynamic Thermal Simulation tool 4. Evaluate the impact of retrofit mashrabiya on indoor comfort, energy consumption and social/cultural aspects as applied to case studies in item 3.

5. Develop and test a prototype mashrabiya that enhances privacy and achieves reductions in energy consumption of buildings in Saudi Arabia.

The research methods:

1. A critical literature review in the area of sustainability and architectural design will be conducted to identify common architectural and operational systems that affect energy consumptions of residential buildings in hot climate. The literature review will also critically evaluate traditional and modern use of Mashrabiya. . This will fulfil objective I ,
2. Interviews with residents of privately owned houses in Jeddah, Saudi Arabia to assess privacy and social needs will be conducted. To assess cultural identity aspects of existing privately owned buildings officials from the Saudi Commission for Tourism and National Heritage and the Jeddah Municipality will be interviewed. This will address objective two.
3. Case studies on three typical houses in Jeddah, Saudi Arabia will be conducted to closely examine and assess building energy performance. This will be achieved through the use of the Dynamic Thermal Simulation tool. This will address objective three.
4. Entry information for the DesignBuilder software will be calculated following the characterisation of three case study houses. A range of simulations will be then conducted to evaluate low energy retrofit mashrabiya for these case study houses in terms of lighting, thermal analysis and indoor environmental quality' . Additionally, optimisation will be tested to propose a set of interventions that would result in reduction in energy consumptions for different designs of mashrabiya. The impact of low energy retrofit mashrabiya on privacy and social cultural issues together with the perception of human indoor environmental quality' will be examined using interviews and questionnaires. This will address objective four.
5. Secondary data from literature review, together with the primary data collected from interviews/questionnaires and the predicted outputs from the dynamic thermal simulations will be used to produce a theoretical framework for the prototype Mashrabiya. The proposed design will then be evaluated for the level of privacy and energy performance through a feedback survey given to residents of buildings with the retrofitted Mashrabiya. This will address objective five.

Section B: Ethical Issues Check List

Please answer the following questions. If you answer YES to any of the following questions then specific ethical issues WILL be raised that MUST be addressed. You will need to explain in detail in the subsequent sections how you will address these ethical issues and if necessary attach additional documentation to the end of this application form as noted below.

Does your proposed research activity involve any of the following research procedures?

3. Activities Checklist	**Please Tick**		**If YES** **Additional documents required to be attached to this application are:**
	YES	**No**	
Conducting Interviews and / or undertaking any of the following: • Making audio or video recordings of identifiable people. • Collection storage and use of personal	!		(i) Participant Information Sheet (Use Template Provided) (ii) Participant Consent Form (Use Template Provided)
data about identifiable, living people. • Observation of adult human behaviour involving identifiable individuals. • Using archived personal data in which living individuals are identifiable.			
Observing, interacting or otherwise working with children (under the age 18)		!	(iii) Parent / Guardian Consent Form (Use Template Provided)
Researching into activities that have a risk of personal injury to the participants		!	(iv) DMU Health and Safety Risk Assessment Form
Supporting innovation that might impact on human behaviour e.g. Behavioural Studies and / or Activities which may pose a physical risk to other people not directly participating in the research		!	
Activities which may pose a risk to the environment		!	(v) DMU COSSH Risk Assessment Form
Researching topics that are concerned with the following **'sensitive research'** areas: illegal activities, including the collection of source data, e.g. crime statistics, or access to web sites normally prohibited on university servers, or extremism and radicalisation		!	(vi) Please complete the questions in Appendix 1 on page 7 of this form to identify if a research project should be classified as sensitive research *before* continuing to complete the main sections.
Anything else that in the opinion of the Applicant and Supervisor that requires further ethical review		!	

Note:

***Participant Information Sheet** – This is available in a DMU approved format for completion by the researcher and explains in straight-forward, non-specialist language what you are doing, why and what you'll do with the data you collect.*

***Participant Consent Form** – This is available in a DMU approved format and when completed by the subject provides written permission for you to use the information elicited from the subject. It includes an Audio / Video Recording Agreement and covers Custody and preservation of data adhering to DMU regulations and procedures.*

***Parent / Guardian Consent Form** - This is available in a DMU approved format and when endorsed provides written permission by the child's Legal Guardian for the researcher to interact with a child and use the information elicited from the child.*

***Sensitive Research Questions Appendix** – Can be found on page 7 of this form and identifies whether the research should be classed as sensitive (For more information see: http://www.dmu.ac.uk/research/ethics-and-governance/sensitiveresearch.aspx).*

DMU health and Safety Risk Assessment Form *– Consult your Faculty Health & safety Officer.*

Environmental Impact Risk Assessment Form *– COSSH Risk assessment form available on DMU website*

Other Documents as required by the Faculty Human Ethics Committee *- Depending on the nature of your proposed research, special circumstances may arise which may require other documents to be submitted in addition to this application form. You will be advised if this is the case on receipt of your initial application.*

Section C: How Ethical Issues Will Be Addressed

If in consultation with your supervisory team (if any) you answered NO to ALL the questions above, please skip sections 4 & 5, go to straight to section 6 and complete the rest of the form. If you answered YES to any of the above questions please complete sections 4 & 5 and then complete the rest of the form.

4. Ethical Issues – Please state briefly the details of all the ethical issues identified.
* Providing full details of the research before participating in the questionnaire, interview, or getting appointed for the interviews * Secure storage of data * Privacy of the participants * Confidentiality * Freedom to withdraw * Anonymity of responses for the questionnaire I focus groups * Voluntary participation. * Information sheet will be provided to give the full information about the project in detail.

5. Please state here how these ethical issues will be addressed:

*Explain to people what the researcher is going to do with full detail.

*Provide information for those whose first language is not English in their native language.

*Fill out consent form and tell them what they are going to do and include details of the study.

*Obtain their permission for conducting interviews or questionnaires with them.

*Send emails or letters with full details about the project to people I am going to interview, and establish an appointment with a suitable time and place for the interview. * Obtain their permission for audio recording their voice during the interview.

Send an email or letter to the interviewee before at least 1 week before the interview to select the appropriate day of the interview.

*Any information obtained from the questionnaire or interviews, will be kept secure and coded to maintain identity of participants confidential.

*The interviewee has the freedom to accept or decline being interviewed. Also, they can stop participating at any time if they do not feel like continuing and they can refuse answering any questions they do not want to answer or give their opinion about. * All original data will be securely saved and locked away in compliance with DMU protocols and the 1998 Data Protection Act (encrypted memory stick)

Note: You should consider the following:

- *Providing participants with full details of the objectives of the research*
- *Providing information appropriate for those whose first language is not English*
- *Voluntary participation with informed consent*
- *Written description of involvement*
- *Freedom to withdraw*
- *Keeping appropriate records*
- *Signed acknowledgement and understanding by participants*
- *Relevant codes of conduct/guidelines*

Section D: Ethical References and Additional Factors

All Applicants MUST complete these sections and do so in consultation with your supervisory team if any:

6. To which ethical codes of conduct have you referred? *see* *http://www.dmu.ac.uk/research/ethics-and*http://www.dmu.ac.uk/research/ethics\and\governance/research\integrity\and\ ethics.aspx*governance/research-integrity-and-ethics.aspx*
To the Faculty of Art, Design & Humanities Ethics Procedures.

7. Are there other additional factors that could/will give rise to ethical concerns e.g. communication difficulties?
No

Section E: Authorization

a .	Signature by Applicant		
I declare that. I have considered the ethlcal Implications of my research. I understand that I must not undertake any research activity until this form is fully approved. A signature & date must be given here or the application will be rejected.			
Signed	**Shafiaa Saad Algha** J____.,,.,	Date	**29-04-2016**

9. Signature by First Supervisor / Tutor (If appllcant **Is a** student)			
I d eclar;e that the person named above will be working under my supervision.			
Print Name	**Dr. Ahmad Taki**	**Print Department**	**School of Architecture**

Signed		Date	, /'

10. Cond1t1onal Approval	11. Unconditional Approval

Section A: Sensitive Research

11. Please answer all of the following questions	Please Tick	
	YES	NO
1. Does the intended research include research into illegal activities[i]? (This may include, but is not limited to, research into hate crime[ii], theft, fraud, or harmful and illegal cultural practices[iii], the collection of source data, such as crime statistics, etc.). ***Please note: the university does not permit any crime to be committed for research purposes, such as accessing images of paedophilia or child abuse, unless special permission has been granted by the Home Office.***		!
2. Does the research involve deception?		!
3. Will the research require the use of sites usually prohibited on university computers (e.g. pornography or the sites of these prohibited organisations)?[iv]		!

4. Has the research been commissioned under a commercial contract requiring secure storage for related materials?		!
5. Does the intended research fit into any of the following categories? If so, please indicate which:		!
a) Terrorism, extremism, terrorist or extremist organisations or groups, extremist ideologies, radicalisation[v], de-radicalisation[vi]		!
b) Commissioned by the military or GCHQ:		!
c) Commissioned under an EU / US security call or similar:		!
d) Involve the acquisition of security clearances (including the Official Secrets Act):		!

***If you are unsure as to whether your research will involve any of these categories you are advised to answer 'Yes' to the most relevant.**

Section B: Accessing Websites for the Research Areas Outlined in Section A, Q5 a- e

12. Please answer the following question	**Please Tick**	
	YES	**NO**
Will your research involve visits to websites that might be associated with radicalisation or terrorist/extremist organisations or groups?		!

If you answer 'Yes' to Q1 you are advised that such sites may be subject to surveillance by the police and accessing those sites might lead to police enquiries. It is strongly recommended that you use your university network address, once you have received ethical approval, which will ensure these activities are flagged as a legitimate part of your research. Whilst acquiring ethical approval for this project and adhering to University *guidance on accessing websites and storing related materials securely will allow the University to verify the legitimacy of you accessing these websites, it cannot guarantee legal protection.*

Please acknowledge that you understand this risk by putting an 'X' in the 'I Agree' box.

I Agree	!

Section C: Storage and Transmission of Research Materials

The secure storage of data and research material is strongly recommended to all who answered 'Yes' in Section A, Q5 (although all researchers may make use of the ITMS provisions detailed in this questionnaire). Please note that anyone storing participants' personal data is subject to separate legislation and requirements. Details are outlined here, and in the university's Research Records Retention Policy.

13. Please answer the following question	Please Tick	
	YES	NO
Does your research involve the downloading and storage on a computer of any materials relating to extremism or radicalisation (for example, records, statements or other documents)?		!

If you answered 'Yes' to Q1, you should request a secure file share from ITMS to be created for your project, with access restricted to you, or if absolutely necessary, any internal co-investigator(s). The research materials should not be kept on a personal computer, and all online research in this area should be done on university servers[vii]. Physical data should be scanned and uploaded to the password-protected server; where this is not possible, it should be kept in a locked filing cabinet or similar on university premises.

You will need to agree to store all materials relevant to Section B, Q1 and Section C, Q2, as well as any other materials related to your research project in accordance with this advice in order to gain ethical approval.

Please confirm you will store *all* research documents in accordance with this advice by putting an 'X' in the 'I Agree' box.

I Agree	!

14. Please answer the following question	Please Tick	
	YES	NO
Might your research involve the electronic transmission of such materials to project Co-Investigators?		!

Note: *The Terrorism Act (2006) and the Counter-Terrorism and Security Act (2015) outlaw the dissemination of terrorist publications if the individual concerned has the intention to encourage or induce others. Publications disseminated for the purposes of an approved and clearly defined research project* *should not amount to an offence, because the requisite intention is unlikely to be present. However, you are advised to exercise caution and avoid dissemination of raw research materials where possible.*

You will need to agree to only transmit these materials to Co-Investigators after they have been password-protected and that you will only use '[Zend](#)[viii]', which encrypts materials in transmission.

I Agree ! By signing this form, you confirm that you have read, understood and will comply with the above ethical procedures relating to conducting sensitive research. You **MUST** also sign the main section of this application form.

Signature	**Date**
Shafiaa Saad ALghamdi	23-11-2016

[i] **Illegal activities** incorporates **any illegal activity;** for example, trespassing, theft, or online piracy. [ii] **Hate Crimes** are those committed against someone because of their disability, gender-identity, race, religion or belief, or sexual orientation.

[iii] **Harmful and illegal cultural practices**: these include violence against women and girls, Female Genital Mutilation (FGM), forced marriage, child sexual exploitation and honour-based violence. [iv] **Accessing prohibited websites:** You will need to seek permission from ITMS; advice on how to gain permission is available from the ITMS helpdesk. [v] **Radicalisation** refers to the process by which a person comes to support terrorism and forms of extremism leading to terrorism

[vi] **De-radicalisation** usually refers to activity aimed at a person who supports terrorism and in some cases has engaged in terrorist related activity, which is intended to effect cognitive and/or behavioural change leading to a new outlook on terrorism and/or disengagement from it. [vii] **Secure File Share:** You will need to ask ITMS to create a Secure File Share for your project, with access restricted to yourself, or if absolutely necessary, any internal co-investigator(s). Advice is available from the ITMS helpdesk.

[viii] **Zend**: advice on using Zend is available from the ITMS helpdesk.

Participant Information Sheet

[The Impact of Mashrabiya on Building Energy Performance and Social Cultural Aspects in Hot Climates]

Please take some time to read this information and ask questions if anything is unclear.

Contact details can be found at the end of this document.

What is the purpose of this study?

This study aims to [determine the impact of mashrabiya on building energy performance and social cultural aspects in the hot climate of Jeddah, Saudi Arabia].

Who is organising this research?

The research for this study is being undertaken by [Shafiaa Saad ALghamdi] who is [doctoral] student in [Faculty of Art, Design & Humanities- Architecture department] at De Montfort University.

De Montfort University Research Ethics Committee has reviewed and approved this research.

Why have I been chosen?

By using the [interview] this project hopes to [Identify the energy performance and examine the privacy and cultural needs of current houses in Jeddah, Saudi Arabia.].

We aim to interview [25] participants from [Jeddah, Saudi Arabia that privately own houses].

Do I have to take part?

Participation in this study is voluntary and you may ask the researcher questions before agreeing to participate. However, we believe that your contribution will assist in [examining energy performance and privacy and social cultural needs of Saudi residents and developing a Mashrabiya that will respond to these needs].

If you agree to participate, you will be asked to sign a consent form. However, at any time, you are free to withdraw from the study and if you choose to withdraw, we will not ask you to give any reasons.

What will happen to me if I take part?

If you agree to take part in this study we will [interview you and audio record the interview].

The interview will be conducted by [Shafiaa ALghamdi] and will last [20-30 minutes].

We may ask you to participate in a follow-up interview, though participation in this is optional.

What are the possible benefits of participating?

The study aims to [develop a prototype Mashrabiya that will suit the needs of Saudi residents as it pertains to the privacy, social cultural needs while enhancing energy performance].

What are the possible risks of taking part?

While we hope that your experience will be pleasant, [the audio recording] may make you uncomfortable. At any time during the interview you can choose to withdraw.

How will my interview be used?

[The interview will be used as secondary data to provide information for this study].

On the consent form we will ask you to confirm that you are happy to assign your (or where relevant, your child or vulnerable adult in your legal charge) copyright for the interview to us, which means that you consent to the researcher using and quoting from your interview.

What will happen to the results of the project?

All the information that we collect about you during the course of the research will be kept strictly confidential. You (or where relevant, your child or vulnerable adult in your legal charge) will not be identified in any reports or publications and your name and other personal information will be anonymised.

What happens to the interviews collected during the study?

Interviews will be [transcribed/audio recorded and stored digitally], managed by the researcher for the duration of the project. Only the researcher and supervisor will have access to the interviews and personal information.

What happens at the end of the project?

If you agree to participate in this project, the research will be written up as a [thesis]. You may request a summary of the research findings by contacting the researcher. On successful submission of the [thesis], it will be deposited both in print and online at De Montfort University, to facilitate its use in further research. The digital online copy of the [thesis] will be deposited with De Montfort Open Research Archive ("**DORA**") and will be published with open access meaning that it will be available to all internet users. At the end of this project, the audio and digital data collected from interviews with participants will be deposited at the UK Data Service for use by future researchers.

What about use of the data in future research?

If you agree to participate in this project, the research may be used by other researchers and regulatory authorities for future research.

Who is funding the research?

[This research is funded by [the Saudi Ministry of Education].] **What**

should I do if I have any concerns or complaints?

If you have any concerns about the project, please speak to the researcher, who should acknowledge your concerns within ten

(10) working days and give you an indication of how your concern will be addressed. If you remain unhappy or wish to make a formal complaint, please contact [**please insert details, name, address and email**].

Fair Processing Statement

This information which you supply and that which may be collected a part of the project will be entered into a filing system or database and will only be accessed by the researcher and supervisor involved in the project. The information will be retained by De Montfort University and will only be used for the purpose of research, statistical and audit and possibly commercial purposes. By supplying this information you are consenting to us storing your information for the purposes above. The information will be processed by use in accordance with the provisions of the Data Protection Act 1998. No identifiable data will be published.

Participant Consent Form

[The Impact of Mashrabiya on Building Energy Performance and Social Cultural Aspects in Hot Climates]

Shafiaa Saad Alghamdi

00447505098376
P15017159@my365.dmu.ac.uk]

This agreement is made in regard to the recorded interview(s) which took place on [June 2017].

In consideration of my participation in the research and other valuable consideration provided by the De Montfort University ("**University**"), I declare the following:

Declaration:

- I confirm that I have read and understood the participant information sheet for this study
- I have had the opportunity to ask questions if necessary and have had these answered satisfactorily
- I understand that my participation is voluntary and that at any time, I am free to withdraw without giving any reason
- If I withdraw, my data will be removed from the study and will be destroyed
- I understand that De Montfort University Ethics Committee has reviewed and approved this study
- I give permission to the University and those authorised by the University to take images of and/or record me for the above project and/or video/film and/or sound recording ("**Recordings**")
- I grant to the University the right and right to authorise others to make the Recordings available across all platforms and in all media (in whole or in part, transcribed or otherwise) in perpetuity throughout the world for educational, research, commercial and promotional purposes at the University, such uses include but not limited to print and online publication and broadcast
- I agree to taking part in the above study and recording, and hereby assign to the University all copyright in my contribution for use in all work resulting from this project and future projects
- I agree that my data may be managed, stored and archived at the University in accordance with the UK Data Protection Act 1998 http://www.dmu.ac.uk/research/research-support/research-data-management.aspx, and that the University may store electronically the information and Recordings outside the European Economic Area (EEA)
- I understand that **my responses will be kept strictly confidential**, that **all my personal and sensitive data will be anonymised in any reports or publication** and **my name will not be identified in any reports or publication**
- I understand that sensitive personal data may be collected during this interview. This may include information relating to race or ethnic origin, political opinions, religious beliefs, physical/mental health, trade union membership, sexual life or criminal activities
- I understand that the research will be written up as a [thesis] by [Shafiaa Saad ALghamdi]
- I give permission to other researchers and regulatory authorities to have access to my data in relevant future research
- I understand how to raise any concerns or complaints about this study
- I am aware that there are no compensation arrangements
- I will inform the researcher should my contact details change
- This consent form shall be governed in all respects by English law and the English courts ***Name, signature and date:***

Name of participant……………………………… Date……………………………… Signature…………………………..

Postal address/phone/email

A copy of the signed and dated consent form and the participant information leaflet should be given to the participant and retained by the researcher to be kept securely on file.

Residents Survey

The Impact of *Mashrabiya* on Building Energy Performance and Social Cultural Aspects in Hot Climates

My name is Shafiaa Alghamdi. I am a PhD student at DE Montfort University, School of Architecture in Leicester, United Kingdom. I am conducting research on 'The Impact of *Mashrabiya* on Building Energy Performance and Social Cultural Aspects in Hot Climates''. We need to collect some information about this study through this questionnaire. My research question is 'How could the Saudi domestic building windows be designed or modified in line with the sustainability principles?' Your participation in this questionnaire will be of great value to this study.

The survey has 23 questions and should take a few minutes to complete.
The information you provide is confidential, except that anonymous quotes may be used. If you request confidentiality, beyond anonymous quotes, information you provide will be treated only as a source of background information, alongside literature<based research and interviews with others. Your name or any other personal identifying information will not appear in any publications resulting from this study; neither will there be anything to identify your place of work or the project you are involved in. The information gained from this interview will only be used for the above objectives, will not be used for any other purpose and will not be recorded in excess of what is required for the research. Even though the study findings will be published in international conferences and journals, only relevant researchers will have access to the survey data itself. These researchers will be bound by the principles outlined above. There are no known or anticipated risks to you as a participant in this study.

Your participation is voluntary. You are permitted to skip any questions that you do not want to answer. At anytime during this questionnaire you may stop and withdraw your participation.

If you have any questions regarding this study or would like additional information please contact [Shafiaa Alghamdi, at 00447505098376
P15017159@my365.dmu.ac.uk

Thank you for your participation!!

Sincerely,

Shafiaa Alghamdi

By filling in this survey you indicate that you understand its purpose and consent to the use of the data as indicated above. Should you decide not to complete the survey, the questions you answered up to that point will be used unless you indicate otherwise in questions 1 and 2.

1. **I agree with the use of my responses for research purposes of the project as outlined above.**

   Yes

   No

2. **I agree to the use of anonymous quotes from my response for research and publication purposes**

   Yes

   No

3. **Gender**
   a. Female
   b. Male
   c. I would rather not say
4. **Age**
   a. 20<30
   b. 31<40
   c. 41<50
   d. 51+
5. **What culture do you most identify with?**
   a. ……………………………………..
6. **Nationality** (if you choose not to respond leave blank)
   a. ……………………………………..
7. **Do you own the house you live in?**
   a. Yes
   b. No
8. **Did you build the house you live in?**
   a. Yes
   b. No
9. **Which type of windows do you have in your house?**

a. Mashrabiya
b. Glass
c. Other (Please indicate) ....

10. **Which type of windows from the list below represent Hijazi culture identity?**
    a. Mashrabiya
    b. Glass
    c. Other (Please indicate) ....

11. **In terms of privacy which type of windows would you prefer?**
    a. Mashrabiya
    b. Glass
    c. Other (Please indicate) ....

12. **Why did you select this type of windows in the previous question?**
    ....
    ....
    ....

13. **On a scale of 1 to 5, with 1 being not important at all and 5 being very important, how important is privacy in your home?**

    1 2 3 4 5

14. **On a scale of 1 to 5, with 1 being totally visible and 5 being completely invisible (where no one can see inside), how do you like your windows to be?**

    1 2 3 4 5

15. **Do you use shutters on the windows in your house?**
    a. Yes
    b. No

16. **If you answered "yes" to the previous question (Question 15), why do you use shutters?**
    a. Provide privacy
    b. Prevent glare
    c. Other (Please indicate)...

17. **Do you use the windows in your house to ventilate the interior?**
    a. Yes
    b. No

18. **If you answered "yes" to the previous question (Question 17) how frequently do you use the window in your house for natural ventilation?**
    a. Usually (every day)
    b. Sometimes (once a week)
    c. Rarely (once a month)
    d. Not at all
19. **Do you use the windows in your house for natural lighting?**
    a. Yes
    b. No
20. **If you answered "no" to the previous question (Question 19) why don't you use the window in your house for natural lighting?**
    a. No privacy
    b. Not easy because the curtain design
    c. Don't enjoy natural lighting
    d. Use artificial lighting
    e. Other (Please indicate) ……………………………………………………
21. **Do the windows you use now affect energy consumption in a positive or negative manner?**
    a. Positive
    b. Negative
    c. I don't know
22. **How much energy (in kilowatt per hour) do you consume on average every month? (Information for this question can be found on your monthly electricity bill statement)**
    a. 1<2000
    b. 2001<4000
    c. 4001< 6000
    d. 6001<8000
    e. 8001<10,000
    f. More than 10,000
23. **How efficient do you think your windows are in regards to energy consumption? Please explain.**

………

………

DE MONTFORT UNIVERSITY LEICESTER

Faculty of Art, Design and Humanities Department of Architecture

Online survey form

Dear

my name is Shafiaa Alghamdi; I am a PhD student at DE Montfort University, school of Architecture in Leicester, United Kingdom. I am doing research on [**The Impact of Mashrabiya on Building Energy Performance and Social Cultural Aspects in Hot Climates]**

''. We need to collect some information about this study.
My research question is '**Can mashrabiya reduce energy consumption**?' and we asking if you would agree to participate in my research by answering a questionnaire or interview.

The survey has 15 questions and should take about five minutes to complete. The information you provide is confidential, except that anonymised quotes may be used. If you request confidentiality, beyond anonymised quotes, information you provide will be treated only as a source of background information, alongside literature-based research and interviews with others.

Your name or any other personal identifying information will not appear in any publications resulting from this study; neither will there be anything to identify your place of work or the project you are involved in.

The information gained from this interview will only be used for the above objectives, will not be used for any other purpose and will not be recorded in excess of what is required for the research.

Even though the study findings will be published in international conferences and journals, only relevant researchers will have access to the survey data itself. These researchers will be bound by the principles outlined above. There are no known or anticipated risks to you as a participant in this study.

If you have any questions regarding this study or would like additional information please contact [Shafiaa Alghamdi, at 00447505098376
P15017159@my365.dmu.ac.uk]

By filling in this survey you indicate that you understand its purpose and consent to the use of the data as indicated above. Should you decide not to complete the survey, the data you have entered up to that point will be used, unless you indicate otherwise in questions 1 and 2?

Thank you for your cooperation.

Yours Sincerely,

Shafiaa Saad Alghamdi

Lecturer at King Abdul Aziz University

College of Art and Design

Department of Interior Design

1. I agree with the use of my responses for research purposes of the project as outlined above.

Yes

No

2. I agree to the use of anonymised quotes from my response for research and publication purposes

Yes

No

Architecture Survey

Thank you for taking the time to participate in this questionnaire!

This questionnaire was developed for a PhD architectural thesis. The collected responses will be analyzed to understand current practices and philosophies of architects and engineering professionals. Your responses will remain confidential and none of the data will be shared with others, only the aggregate analytical findings will be incorporated in the final thesis.

This questionnaire consists of multiple choice and short answer questions. The first few questions capture demographic information about you. The remaining questions relate to your architectural design philosophy and opinions regarding the use of mashrabiyya.

The survey should take no longer than 10\15 minutes to complete. Please be honest with your responses, this questionnaire is completely anonymous.

Thank you for participating and feel free to encourage your colleagues to participate!

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Specialism? *

Nationality?

Years of experience *

- 1 \ 5
- 6 \ 10
- 11 \ 15
- 16 \ 20
- 20 +

Which architecture system can reduce energy consumption in residential buildings? Write your idea below.

With insulated buildings which of architecture systems below are the major cause of increase in energy usage?

- ○ Roof
- ○ Walls
- ○ Doors
- ○ Windows

From 1\ 5 rate which of the operational systems can more energy consumption in residential buildings? 1 being the lowest. Circle the appropriate answer.

	Lowest				Highest
Air Condition	1	2	3	4	5
Lighting	1	2	3	4	5
Heating	1	2	3	4	5
Refrigerator	1	2	3	4	5
Appliance	1	2	3	4	5

In your opinion do the contemporary residential building reflect the identity of Jeddah architecture (Hejazi Architecture)? Choose you answer.

- ○ Totally disagree
- ○ Disagree
- ○ Agree
- ○ Totally agree
- ○ Not sure

Do you think a glass window provides privacy in residential building? Why? Tick appropriate answer.

- Yes
- No
- Why?...

Will the use of Mashrabiya reduce energy consumption in the insulated buildings in Jeddah? Choose you answer.

- Yes
- No
- Maybe

Do you think Mashrabiya should be re\instated in the new residential building in Jeddah?

- Totally disagree.
- Disagree
- Agree
- Totally agree.
- Not sure

Explain how Mashrabiya should be developed to reduce energy consumption and suit the modern style using air condition?

<u>government Organization Letter</u>

بسم الله الرحمن الرحيم

السادة امانة محافظة جدة المحترمين

السلام عليكم و رحمة الله و بركاته

انا طالبة دكتوراة مبتعثة من جامعة الملك عبد العزيز الى جامعة دي مونت فورت في مدينة ليستر بالمملكة المتحدة قسم العمارة اعمل حاليا على بحث بعنوان (اثر المشربية "الروشان" في آداء طاقة المباني و العناصر الاجتماعية و الثقافية في المناخ الحار) و يتطلب البحث عقد لقاءآت مع موظفي قسم التخطيط و التعمير في امانة محافظة جدة من تاريخ ٢٣/ ٢٧ صفر ١٤٣٩ الموافق ١٢ /١٦ نوفمبر ٢٠١٧ م. إن هذا الجزء هام جدا لبرنامجي وسيسهم في تحسين الإستفادة من العناصر المستدامة التي تساهم في توفير الطاقة في المباني.

في حال الموافقة ارجو بخطاب يفيد بذلك على عنواني البريدي ادناه مع نسخة عاجلة (بي دي إف) على البريد الإلكتروني.

شاكرة لكم حسن تعاونكم

شفياء سعدبن رافعة الغامدي

جامعة دي مونت فورت

ليستر – المملكة المتحدة

Dear Jeddah Municipality

I am a PhD researcher from King Abdul Aziz University and attending my program at DE Montfort University in Leicester, United Kingdom. My topic is “THE IMPACT OF MASHRABIYA ON BUILDING ENERGY PERFORMANCE AND SOCIAL, CULTURAL ASPECTS IN HOT CLIMATES” and my research includes conducting interviews with specialist from your organization “Jeddah Municipality” in Jeddah city. I am planning to conduct the interview from 12-16 November 2017. These interviews are essential for my program and will result in improving the utilization of sustainable architectural elements that conserve energy. Please let me know in writing if you can confirm this on the indicated date period.

Shafiaa S Alghamdi

61 Mill Lane, Vijay Building, Room 2.31

Leicester, LE1 9BH

United Kingdom

Email : P15017159@my365.dmu.ac.uk **Tel : +447505098376**

بسم الله الرحمن الرحيم

سعادة مدير كهرباء جدة المحترم

السلام عليكم و رحمة الله و بركاته

انا طالبة دكتوراة مبتعثة من جامعة الملك عبد العزيز الى جامعة دي مونت فورت في مدينة ليستر بالمملكة المتحدة قسم العمارة اعمل حاليا على بحث بعنوان (اثر المشربية "الروشان" في آداء طاقة المباني و العناصر الاجتماعية و الثقافية في المناخ الحار) ويتطلب البحث عقد لقاءآت مع المختصين في وسائل ترشيد الإستهلاك في الشركة السعودية للكهرباء في مدينة جدة في حين الموافقة على ذلك ارجو الرد بخطاب يفيد ذلك. إن هذا الجزء هام جدا لبرنامجي وسيسهم في تحسين الإستفادة من العناصر المستدامة التي توفر الطاقة في المباني.

شفياء سعد الغامدي

جامعة دي مونت فورت

ليستر – المملكة المتحدة

Dear Saudi Electricity Company

I am a PhD researcher from King Abdul Aziz University and attending my program at DE Montfort University in Leicester, United Kingdom. My topic is "THE IMPACT OF MASHRABIYA ON BUILDING ENERGY PERFORMANCE AND SOCIAL CULTURAL ASPECTS IN HOT CLIMATES" and my research includes conducting interviews with specialist from your organization "Saudi Electricity Company" in Jeddah city.

Shafiaa S Alghamdi

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بسم الله الرحمن الرحيم

السادة الهيئة العامة للسياحة والتراث لمحترمين

السلام عليكم و رحمة الله و بركاته

انا طالبة دكتوراة مبتعثة من جامعة الملك عبد العزيز الى جامعة دي مونت فورت في مدينة ليستر بالمملكة المتحدة قسم العمارة اعمل حاليا على بحث بعنوان(اثر المشربية "الروشان" في آداء طاقة المباني و عناصر اجتماعية و ثقافية في المناخ الحار) و يتطلب البحث عقد لقاءآت مع موظفين في هيئة السياحة و التراث في مدينة جدة من تاريخ ١١ إلى ١٥ محرم ١٤٣٩ هـ الموافق ١ إلى-٥ اكتوبر ٢٠١٧م.

إن هذا الجزء هام جدا لبرنامجي وسيسهم في اعادة استخدام العناصر التراثية بشقها الوظيفي المتمثل في المحافظة على الطاقة وشقها الجمالي والتراثي والثقافي.

في حال الموافقة ارجو بخطاب يفيد بذلك على عنواني البريدي ادناه مع نسخة (بي دي إف) على البريد الإلكتروني.

شفياء سعد بن رافعة الغامدي

جامعة دي مونت فورت

ليستر – المملكة المتحدة

Dear Saudi Commission for Tourism &National Heritage.
I am a PhD researcher from King Abdul Aziz University and attending my program at DE Montfort University in Leicester, United Kingdom. My topic is "THE IMPACT OF MASHRABIYA ON BUILDING ENERGY PERFORMANCE AND SOCIAL CULTURAL ASPECTS IN HOT CLIMATES" and my research includes conducting interviews with specialist from your organization "Saudi Commission for Tourism & National Heritage" in Jeddah city. I am planning to conduct the interview in the first week 1-5 of October 2017. Please let me know in writing if you can confirm this date .period

Shafiaa S Alghamdi

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بسم الله الرحمن الرحيم

السادة احمد العبيكان للإستثمارات العقارية المحترمين

السلام عليكم و رحمة الله و بركاته

انا طالبة دكتوراة مبتعثة من جامعة الملك عبد العزيز الى جامعة دي مونت فورت في مدينة ليستر بالمملكة المتحدة قسم العمارة اعمل حاليا على بحث بعنوان(اثر المشربية "الروشان" في آداء طاقة المباني والعناصر الاجتماعية والثقافية في المناخ الحار) و يتطلب البحث عقد لقاءآت مع سكان 45 فلة تمليك في حي البساتين في مدينة جدة من تاريخ ٢٥ محرم الى ١٢ ربيع اول ١٤٣٩ هـ الموافق ١٥ اكتوبر إلى ١٤ ديسمبر ٢٠١٧م بمعدل خمس مساكن اسبوعيا، آمل تزويدي بأرقام الراغبين في المشاركة من عملاءكم في الحي والرد بخطاب يفيد بذلك على عنواني البريدي ادناه مع نسخة (بي دي إف) على البريد الإلكتروني .

.

شاكرة لكم حسن تعاونكم

شفياء سعد الغامدي

جامعة دي مونت فورت

ليستر – المملكة المتحدة

Ahmed Al Obeikan for Real Estate Investment

I am a PhD researcher from King Abdul Aziz University and attending my program at DE Montfort University in Leicester, United Kingdom. My topic is "THE IMPACT OF MASHRABIYA ON BUILDING ENERGY PERFORMANCE AND SOCIAL, CULTURAL ASPECTS IN HOT CLIMATES" and my research includes conducting interviews with 45 residents who own their home from ALbasateen district in Jeddah city. I am planning to conduct the interview from 15 of October to 14 of December 2017 (5) residents a week. Please let me know in writing if you can provide contact info among your customers.

Shafiaa S Alghamdi

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أمانة جدة

المملكة العربية السعودية
وزارة الشئون البلدية والقروية
أمانة محافظة جدة

الرقم ________________
التاريخ ________________
المرفقات ________________

الموضوع: بخصوص طلب عقد لقاءات مع موظفي
قسم التخطيط والتعمير في أمانة محافظة جدة

سعادة المهندسة شيماء سعد الغامدي   الموقرة

السلام عليكم ورحمة الله وبركاته . . .

بناءً على خطابكم الموجه الى امانة جدة بتاريخ ٢٠١٧/٨/٢٧ م بشـــأن طلب عقد لقاءات مع موظفي وكالة التعمير في أمانة محافظة جدة.

ومن منطلق توجه أمانة محافظة جدة لدعم الأبحاث العلمية وطلاب البحث العلمي والاتفاقيات المشـــتركة مع جامعة الملك عبد العزيز لدعم الطلاب وامدادهم بما هو متوفر لدينا من بيانات وعليه نود ان نعلم ســـعادتكم بموافقتنا على عقد اللقاءات المطلوبة من الفترة بين تاريخ ٤ إلى ٨ محرم ١٤٣٩ هـ الموافق ٢٤ إلى ٢٨ من سبتمبر ٢٠١٧ م.

وتفضلوا معاليكم بقبول أطيب التحية والتقدير .....

مدير إدارة نظم المعلومات الجغرافية

م. ياسر بن عبيد الله المحمدي

35

Government organization questionnaire

Jeddah Municipality Architecture Interview
2 Interviewees

PERSONAL INFORMATION

1- Occupation? *
2- Specialism? *
3- Nationality?
4- Years of experience *

ENERGY

5- Are you satisfied with the level of energy reduction in insulated residential buildings? Why?
   - Yes
   - No
   - Not sure

BUILDING ENVELOPE

6- Which part of building envelope can reduce energy consumption in residential buildings? On the scale of one to four, one being the highest rank the following architectural system.
   1. Roof
   2. Exterior walls
   3. Doors
   4. Window

7- With insulated residential buildings which of architectural systems below are the major cause of increase in energy usage. On the scale of one to four, one being the highest rank the following architectural system.

1. Roof
2. Exterior walls
3. Doors
4. Windows

8- From 1- 5 rate which of the operational systems can more energy consumption in residential buildings? 1 being the lowest. Circle the appropriate answer.

	Lowest	→			Highest
Air Condition	1	2	3	4	5
Lighting	1	2	3	4	5
Heating	1	2	3	4	5
Refrigerator	1	2	3	4	5
Appliance	1	2	3	4	5

IDENTITY

9- In your opinion, do the contemporary residential buildings reflect the identity of Jeddah architecture (Hejazi Architecture)? Choose you answer.

- Totally disagree.
- Disagree
- Agree
- Totally agree.
- Not sure

10- Which architectural element reflect the (Hejazi Architecture)?

11- What do you think should be done to reflect the heritage architectural identity in contemporary buildings?

12- Will the use of Mashrabiya enhance the identity of traditional architecture 'Hejazi architecture 'in Jeddah? Choose you answer.

- Yes
- No
- Maybe

MASHRABIYA

13- Do you know what Mashrabiya is?

14- Do you think Mashrabiya should be re-instated in the new residential building in Jeddah?

- Totally disagree.
- Disagree
- Agree
- Totally agree.
- Not sure

15- Do you think the use of Mashrabiya will reduce energy consumption in the insulated buildings in Jeddah?

- Yes
- No
- Not sure

16- What do you think would be suitable materials for an improved Mashrabiya?

17- Explain how Mashrabiya could be modified to enhance the identity of traditional architecture and suit the modern style?

18- Which government agency is responsible for setting laws for residential buildings façade to reflect the identity of the city architecture?

19- In your opinion should the government set regulations for residential buildings façade to reflect the city identity.

Saudi Electricity Company

2 Interviewees

PERSONAL INFORMATION

1- Occupation? *
2- Specialism? *
3- Nationality?
4- Years of experience *

ENERGY

5- Are you satisfied with the level of energy reduction in insulated residential buildings? Why?

- o Yes
- o No
- o Not sure

BUILDING ENVELOPE

6- Rate each of the following operational systems in terms of the contribution to energy consumption in residential buildings? One being the lowest. Circle the appropriate answer.

Lowest → Highest

	1	2	3	4	5
Air Condition	o	o	o	o	o
Lighting	o	o	o	o	o
Heating	o	o	o	o	o
Refrigerator	o	o	o	o	o
Appliance	o	o	o	o	o

7- Rate each of the following elements, which contribute to the highest increase in energy consumption. On the scale of one to four, one is the highest rank the following elements.

Lowest ⟶ Highest

	1	2	3	4	5
Roof	o	o	o	o	o
Exterior walls	o	o	o	o	o
Doors	o	o	o	o	o
Windows	o	o	o	o	o

8- Which part of the <u>building envelope</u> can reduce energy consumption in residential buildings? On the scale of one to four, one being the highest rank the following architectural system.

Lowest ⟶ Highest

	1	2	3	4	5
Roof	o	o	o	o	o
Exterior walls	o	o	o	o	o
Doors	o	o	o	o	o
Windows	o	o	o	o	o

MASHRABIYA

9- Do you know what Mashrabiya is?

10- What are the main functions of Mashrabiya?

11- Do you think the use of Mashrabiya will reduce energy consumption in the insulated buildings in Jeddah?

- Yes
- No
- Not sure

12- What would do you think would be suitable materials for an improved Mashrabiya?

13- Explain how Mashrabiya could be modified to enhance the identity of traditional architecture and suit the modern style?

Saudi Energy Efficiency Centre

3 Interviewees

General Information

1- Occupation?
2- Specialism?
3- Nationality?
4- Years of experience

ENERGY

5- Are you satisfied with the level of energy reduction in insulated residential buildings? Why?

- o Yes

- o No

- o Not sure

6- What are the factors that resulted in the estimations of energy reduction for 2030?

BUILDING ENVELOPE

7- Rate each of the following operational systems in terms of the contribution to energy consumption in residential buildings? One being the lowest. Circle the appropriate answer.

Lowest → Highest

	1	2	3	4	5
Air Condition	o	o	o	o	o
Lighting	o	o	o	o	o
Heating	o	o	o	o	o

Refrigerator	o	o	o	o	o
Appliance	o	o	o	o	o

8- Rate each of the following elements, which contribute to the highest increase in energy consumption. On the scale of one to four, one is the highest rank the following elements.

Lowest ⟹ Highest

	1	2	3	4	5
Roof	o	o	o	o	o
Exterior walls	o	o	o	o	o
Doors	o	o	o	o	o
Windows	o	o	o	o	o

9- Which part of the building envelope can reduce energy consumption in residential buildings? On the scale of one to four, one being the highest rank the following architectural system.

Lowest ⟹ Highest

	1	2	3	4	5
Roof	o	o	o	o	o
Exterior walls	o	o	o	o	o
Doors	o	o	o	o	o
Windows	o	o	o	o	o

MASHARABIYA

10- Do you know what Mashrabiya is?

11- What are the main functions of Mashrabiya?

12- Do you think the use of Mashrabiya will reduce energy consumption in the insulated buildings in Jeddah?

13- What would do you think would be suitable materials for an improved Mashrabiya?

14- What are the factors that resulted in the estimations of energy consumption for 2030?

Saudi Commission for Tourism and Natural Heritage

1 Interviewee

General Information

1- Occupation?
2- Specialism?
3- Nationality?
4- Years of experience in this department

IDENTITY

5- Which architectural elements reflect Hejazi Architecture?
6- In your opinion which architectural element would you consider to be the most significant element?
7- In your opinion, do the contemporary residential buildings reflect the identity of Jeddah architecture (Hejazi Architecture)?

- Totally disagree.
- Disagree
- Agree
- Totally agree.
- Not sure

8- Do you think Mashrabiya should be re-instated in the new residential building in Jeddah to enhance the identity of city architecture?

- Totally disagree.

- Disagree
- Agree
- Totally agree.
- Not sure

9- What do you think should be done to reflect the heritage architectural identity in contemporary buildings?

MASHRABIYA

10- Do you know Mashrabiya?

11- Will the use of Mashrabiya enhance the identity of traditional architecture ‘Hejazi architecture ‘in Jeddah? Select the correct answer.

- Yes
- No
- Not sure

12- Explain how Mashrabiya can be modified to enhance the identity of the traditional architecture to suit the modern style?

GOVERNMENT

13- In your opinion, should the government set regulations for residential buildings façade to reflect the city identity?

14- Which government agency is responsible for setting laws for residential buildings façade to reflect the identity of the city architecture?

Al- Basateen resident's interview questionnaire
48 Interviewees

I would like to express my thanks and appreciate your time for anticipating and completing this questionnaire. All information provided in this form will be confidentially and …

….. for the purpose of this study on developing an architectural conceptual design model for new housing sustainability in Jeddah.

Could you please complete all the following questions and write any further comments in the space provided? For further queries, please contact the researcher on the following links:

Email: shafia.rafeah@gmail.com Telephone No. +447505098376

General information

1. Name: ……………………… 2. Age………… 3. Gender………………….

4. Marital status……………. 5.No of family………… 6. Job…………

7. Level of education……………… 8. Area ……………9. City………………

Building information		
Type of home	Villa	Duplex
Type of ownership	Owned	Rented
Date of built		
Area of land		
Area of house		
No of storeys		
No of façade's		

Façades information			
**	No of windows	No of balconies	Others opening
Northern façade			
Southern façade			
Easters façade			
Western façade			

Construction information	
Type of construction material	
Type of thermal insulation	
Outer finishing	
Type of glazing	

Air Conditioning information				
Zone	No of room	No of AC	Capacity of AC	Operational hours
Bedrooms				
Living room				
Guest room				
Kitchen				
Bathroom				

General indoor indoor environmental quality' evaluation					
Parameters	Very suitable	suitable	Kind of suitable	Not suitable	Not at all suitable
	5	4	3	2	1
Natural ventilation					
Natural lighting					
Artificial ventilation					
Artificial lighting					

Air movement					
Humidity					

General indoor indoor environmental quality' importance					
Parameters	Very important	important	Kind of important	Not important	Not important at all
	5	4	3	2	1
Natural ventilation					
Natural lighting					
Artificial ventilation					
Artificial lighting					
Air movement					
Humidity					

Comparison of the thermal environment between outside and inside			
***	Outside	Living room	Room not used
Temperature			
Humidity			
Air movement			
Daylighting			
Artificial lighting			

Living room parameters			
AC set point			
Area of the living room			
Height of ceiling			
Interior wall finishing			
Wall colour			

Floor finishing			
No of furniture			
No of windows			
Area of windows			
Type of glazing			
Window shading	Curtain	Black out	Shutter
Type of lighting	Natural lighting	Artificial lighting	
Type of artificial lighting use	Florescent	Halogen	Economic lighting

Energy consumption

10. In which season do you use?

Autumn - summer - spring - winter

11. What is the preferred set point?

12. How many appliances do you have in your kitchen?

- Electric cooker - Refrigerator - Microwave - Boiler
- Freezer - Extractor hood - Iron - Electric kettle
- Other state……………………………………………………….

13. How many appliances do you have in your house?

- TV - Computer - Washing machine - Dryer.
- Hoover Boiler
- Others state………………………………………………………….……………………

14. How much do you pay annually for electricity?..

15. Are you satisfied with your bill?

- Yes - No

16. Do you have any suggestions to reduce energy usage in the future?

- Yes - No
- How?...

Visual privacy and architecture identity

17. Are you satisfied with privacy in your home between you and your neighbour?

- Yes - No
- Why?

……………………………………………………………………………

18. What you use to provide privacy in your home?

19. Are you using window for natural ventilation and cooling?

- Yes - No
- Why? ……………………………………………………………………………

20. What the average time for the use of the window for natural ventilation and cooling?

21. Do you know Mashrabiya, Roshan?

- Yes - No

22. Do you know Mashrabiya functions?

- Yes - No

- What is it? ……………………………………………………………………………

23. Why did you not use Mashrabiya instead of the glass windows?

24. What is the significant architectural element which reflect Hijazi architecture?

25. Dose the modern residential building reflect Hijazi architecture?

    -Yes - No

    Why?..
    ..

26. Do you think Jeddah lost its architecture identity?

    - Yes - No
    - How? ……………………………………………………………………………..

27. How can Mashrabiya be improved to suite modern lifestyle?

28. Do you care about the design and material for improved Mashrabiya?

29. What do you think the future Mashrabiya should look like?

30. Do you think the modern residential building are more suitable for the local climate?

    - Yes - No
    - Why? ………………………………………………………………………………

31. Do you think the traditional residential building are more suitable for the local environment than modern residential building?

    - Yes - No
    - Why? ……………………………………………………………………

32. Is it possible to make modification to traditional residential building in Jeddah to meet the climatic needs of the society in the 21st century?

- Yes - No
- How?..
.....

33. Do you think the cost of construction and material of construction affect the design and general appearance of the building?
    - Yes - No
    - How?
    ………………………………………………………………………………
34. What do you think would be the best model for residential building suitable for the Jeddah climate and needs of people?
35. Do you have the knowledge of sustainable and environmentally friendly building?

<u>Pilot Survey Results</u>

Pilot Survey Results

According to the pilot survey results, all the three sampled villas were owned and built by the residents themselves. This sample validates the aims of the research to interview homeowners with the choice of architectural elements for the building, especially the choice to use *mashrabiya.* The selected villas have double glazed windows, two with PVC frames and the other with aluminium. All interviewees acknowledged that *mashrabiya* represent Hejazi cultural identity; however, in terms of privacy, one of the residents preferred *mashrabiya* due to the provision of natural light and ventilation while those who chose glass windows with curtains highlighted the advantages of natural light and the usability of the curtain. One resident noted preference in relation to privacy in the home for the windows, while two interviewees noted slightly lower levels of privacy. On the question of the use of a shutter, the reason two of the subjects used them was purely for security purposes while the other did not use shutters at all. The reasons for using the window for ventilation was the same for all residents, while the frequency with which they opened the window to ventilate varied from between residents, as two mentioned once per week and one stated once per month. As to the use of artificial and natural light, two mentioned the use of the window for natural light and one artificial.

As to whether the present windows were energy efficient, all the interviewees claimed this was the case, however on asking the same question in a different way, i.e., as to the efficiency of the window with regard to energy consumption, the responses then given contradicted their previous claims. The energy consumption per month for residents differed per month as one used between 6,001 - 8,000, the other 8,001 – 10,000, and the last more than 10,000 kWh. It is questionable as to why there is a great difference in energy consumption for the residents when all the villas are located in the same area, on the same storey and housed more or less the same numbers of people. This could be due to several factors such as orientation, type of wall and its thickness, and type of roof insulation, but which would be verified in the final interview. On the question as to why residents did not use *mashrabiya*, all claimed to like *mashrabiya* but did not use them as they were not readily available for purchase, collected dust, and were difficult to clean, while the last interviewee merely preferred Western styling to the traditional.

Exterior and Interior design of the interviewees’ windows (Source: Alghamdi 2017)

FExterior and interior designs of the interviewees’ windows (Source: Alghamdi 2017)

The use of shutters on the window exteriors (Source: Alghamdi 2017)

All three homes used double glazed windows with different types of frame, namely PVC or aluminium. Two homes in the sample used shutters in the windows while the latter used only curtains.

The diagram below shows the three villas chosen for the pilot study. The figures in relation to the total area show villa A and B to be the same, while for villa C has a total area that is 600 square metres lower than the others, yet the built area and floor height is the same for all three. It is interesting to note that in terms of energy consumption, Villa C is the lowest at between 6001-8000 kWh while villa B is the highest with over 10 000 kWh while villa A is the second highest with figures between 8001-10000 kWh. Villa A and C have the same number of occupants, yet the amount of electricity consumed is different, with villa A recording more than villa C.

Table 0-0 Statistics for Three homes in Albasateen. (Source: Alghamdi 2017)

Parameters		Values	
	Villa A	**Villa B**	**Villa C**
No. Of floors	3	3	3
Total area	900 m^2	900 m^2	600 m^2
Built area	1350 m^2	1350 m^2	900 m^2
Floor height	3 m	3 m	3 m
Number of users	6	7	6
Orientation	South	South east	South west
HVAC	Central system	Central system	Central system
Type of window	PVC double glazed	PVC double glazed	Aluminium double-glazed
Using Shutters	Yes	Yes	No
Energy consumption kWh	8001-10,000	+ 10,000	6001-8000

Online Questionnaire Results

Online Questionnaire Results

Gender

f	179
m	81

Age

20-30	31-40	41-50	+51
37	81	97	45

Education

degree	master	doctorate	other
169	40	15	34

Family number

1-4	5-7	8-10	+11
81	141	32	6

City

Jeddah	Other
180	80

District name

Albasateen	AL Murjan	Alshatee	Almohammadia	Abhor	AL Naeem	Other
36	1	7	10	23	8	175

Type of house

apartment	Villa	Other

113	123	24

Own the house.

Yes	No
166	94

Build house.

Yes	No
90	170

House age

1-5	6-10	11-15	16-20	+20
63	58	53	41	45

Lived in house.

Less than 8 years	More than 8 years
133	127

Use thermal insulation.

Yes	No
143	117

Type of construction materials

Hollow concrete	Red block	Volcano block	Insulated concrete	Sib Co block	Two walls without insolation	Two walls with insolation	Other
24	129	10	30	11	6	20	30

Type of glazing

Single	Double	Triple	Other
84	154	9	13

Level of privacy

100%	75%	50%	25%	0%
72	87	54	31	16

Façades number

1	2	3	4
128	76	34	22

Have AC

Yes	No
216	44

Average of use AC in living room

Less than 6 hors	6-12	13-18	24
36	147	61	16

Electric annual cost

Less than 5000	5001-10000	10001-15000	15001-20000	20001-25000	25001-30000	+30000
96	97	36	18	3	8	2

Satisfied with the cost.

Yes	No

82	178

Know Mashrabiya.

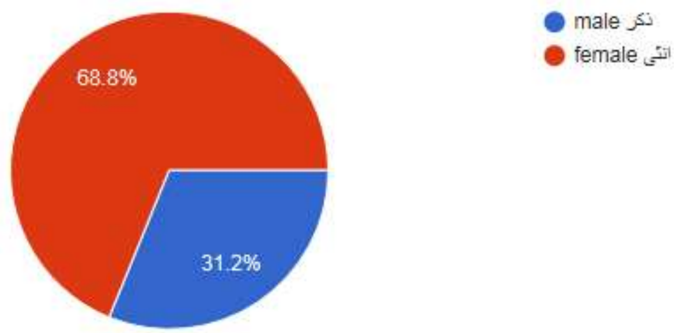
Yes	No
189	71

Use Mashrabiya.

Yes	No
249	11

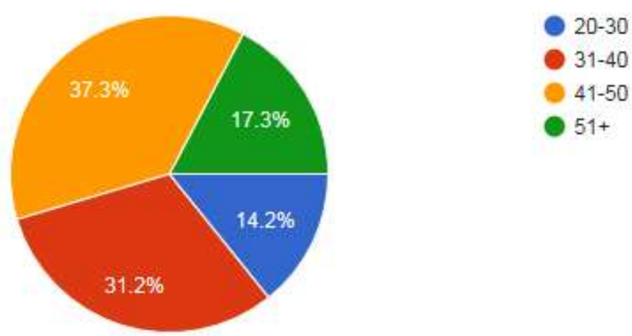
1- Gender الجنس

260 responses



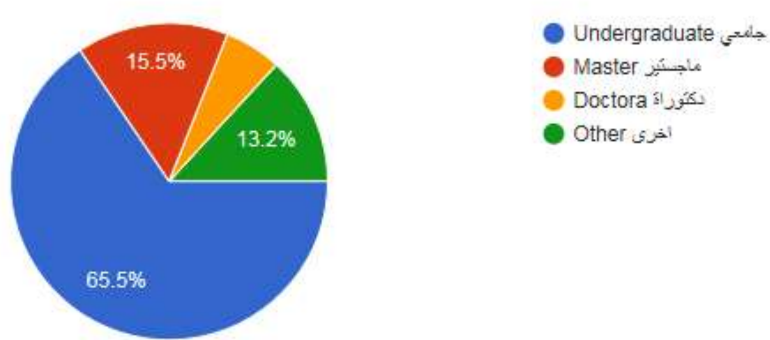
2- Age العمر

260 responses



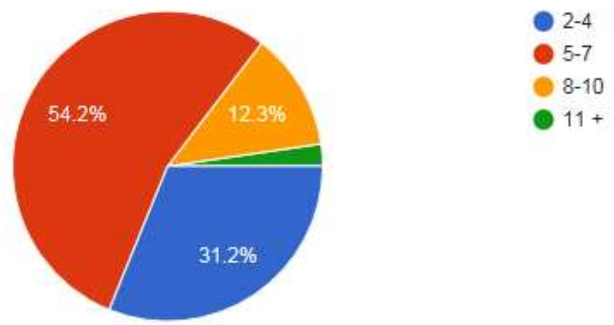
6- Level of education? الدرجة العلمية؟

258 responses



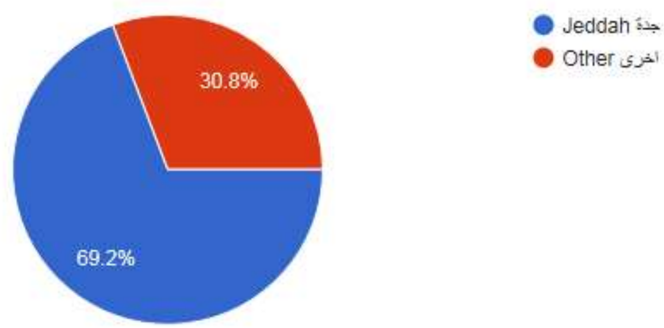
5- Number of people living in the house? عدد افراد الاسرة اللذين يعيشون في المسكن؟

260 responses



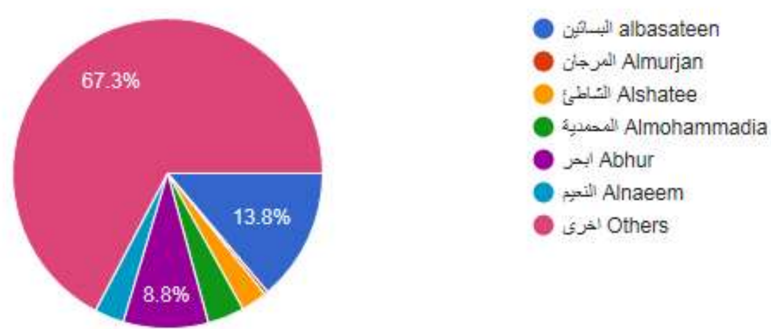
3- City of residence? اسم المدينة التي تسكن بها؟

260 responses



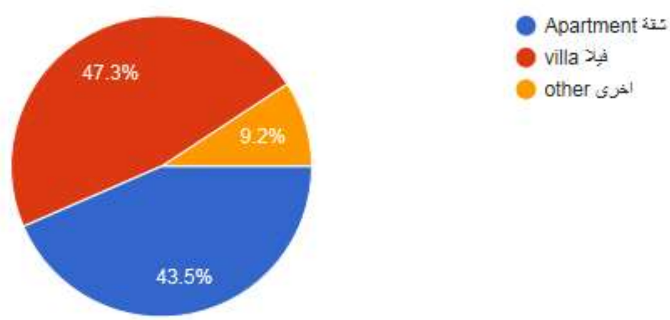
4- Name of district that you live in ? اسم الحي الذي تسكن فيه؟

260 responses



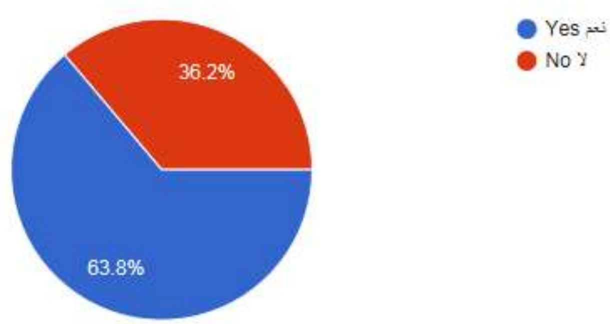
7- What is the type of your house? ما هو نوع المسكن؟

260 responses



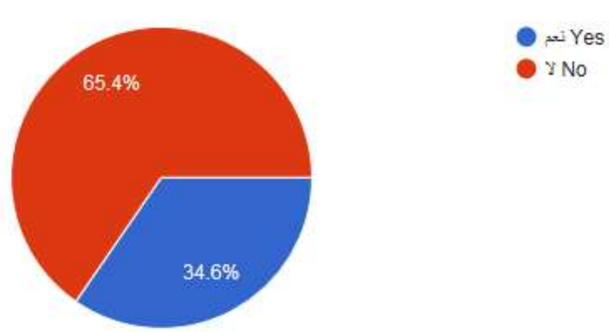
8- Do you own the house? هل تمتلك المسكن الذي تسكن فيه ؟

260 responses



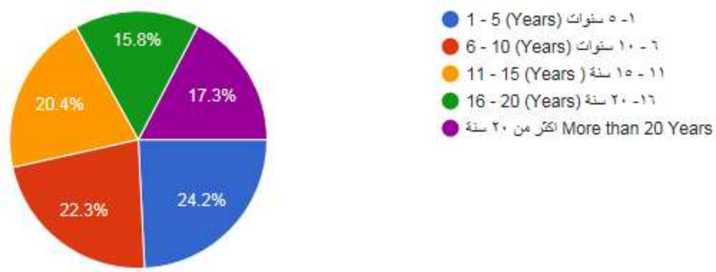
9- Did you build your house ? هل انت من بنى المسكن الذي تسكن فيه ؟

260 responses



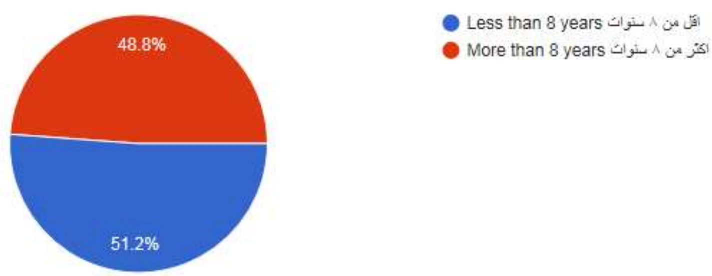
10- What is the age of the building? كم هو عمر المبنى؟

260 responses



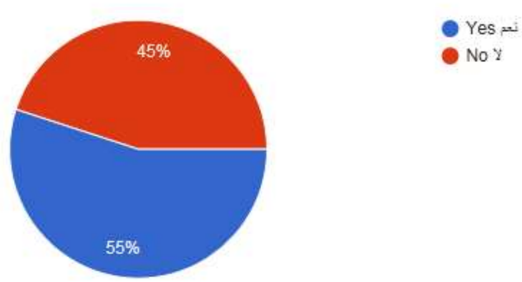
11- How many years have you lived in your current house? ما عدد سنوات السكن في هذا المسكن؟

260 responses



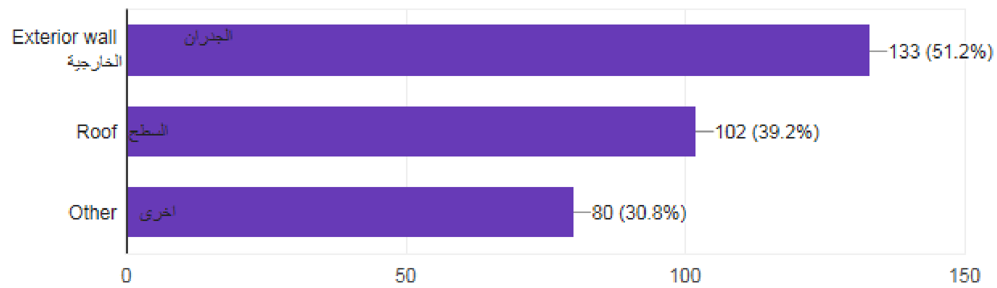
12 - Do you use thermal insulation in your house? هل تستخدم عوازل حرارية في المسكن؟

260 responses



13 - Which part of your house is insulated? You can choose more than one, اجابة

260 responses

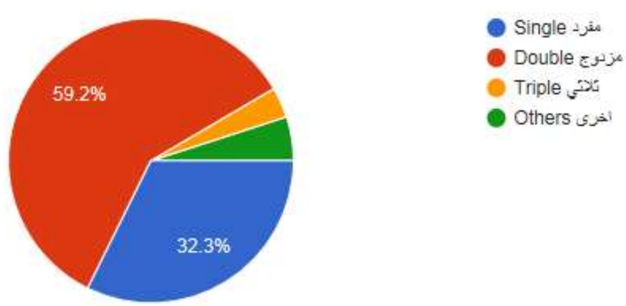


14- What materials are used to build external walls? لمستخدمة في بناء الجدران الخارجية ؟

260 responses

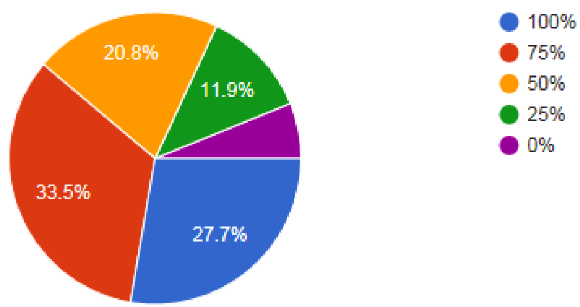
15 - What type of glass do you use in windows? ما هو نوع الزجاج المستخدم في النوافذ؟

260 responses



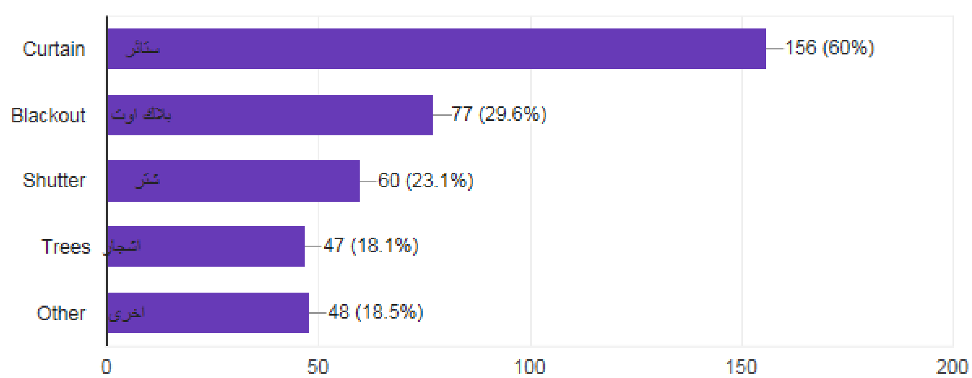
19 - What is the level of privacy on the windows in your home and with neighbours?

260 responses



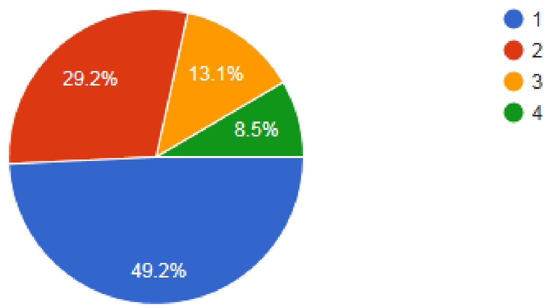
20 - What do you use to provide privacy in you house?You can choose more than or

260 responses



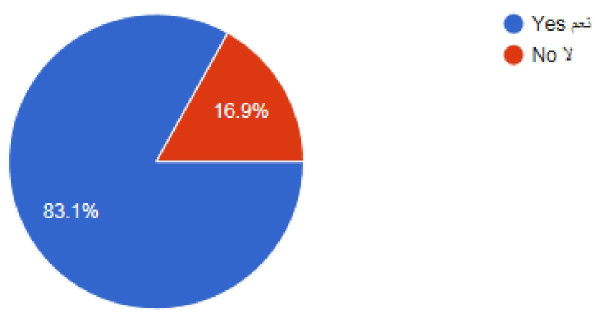
21 - How many façades does your house have? كم عدد واجهات المسكن ؟

260 responses



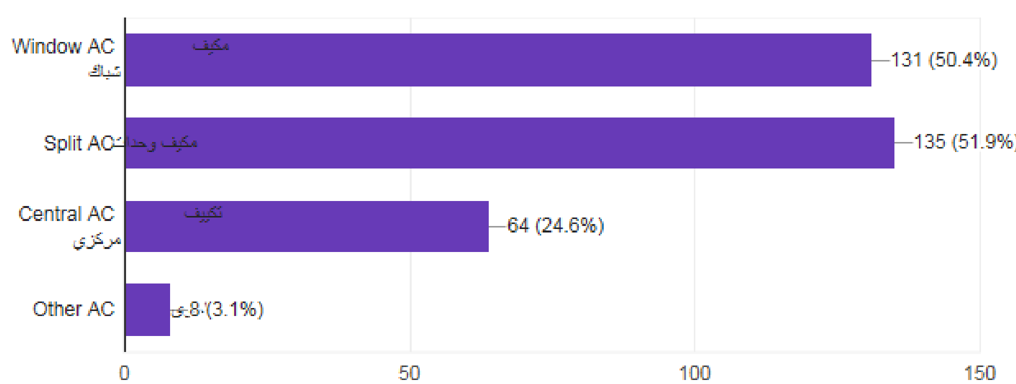
22 - Do you have any Air conditioning system in your home? لديك نظام تكييف في المسكن؟

260 responses



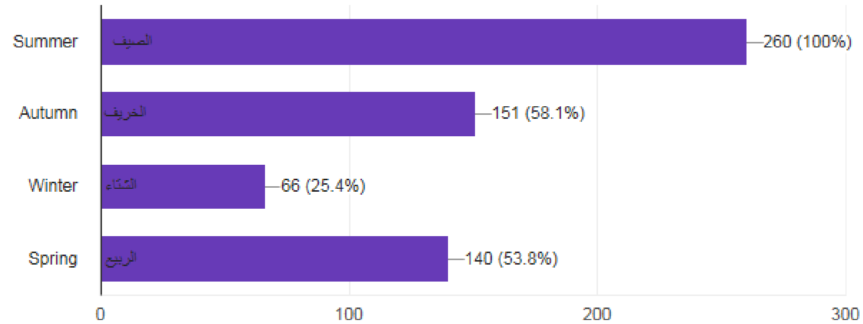
23 - What type of Air conditioning is it? You can choose more than one, ثر من اجابة؟

260 responses



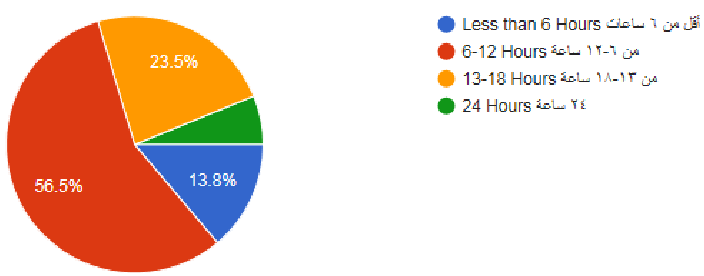
25 - When do you use the Air Conditioning system the most? You can choose more than one, ابة

260 responses



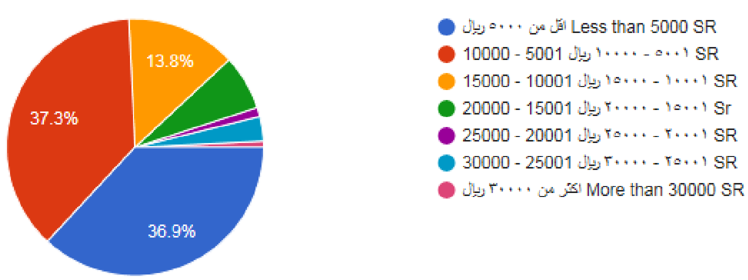
26 - What the daily average of using the AC used in the living room? ت استخدام التكييف في غرفة المعيشة ؟

260 responses



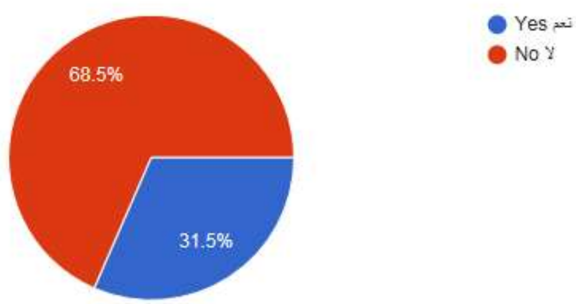
27 - What is your annual cost of electricity bill? ما هي تكلفة فاتورة الكهرباء السنوية؟

260 responses



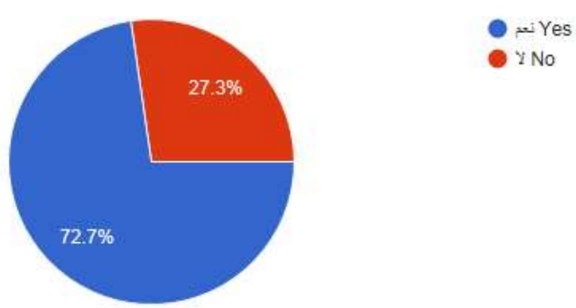
28 - Are you satisfied with the cost of the electricity bill? ت راض عن تكلفة فاتورة الكهرباء؟

260 responses



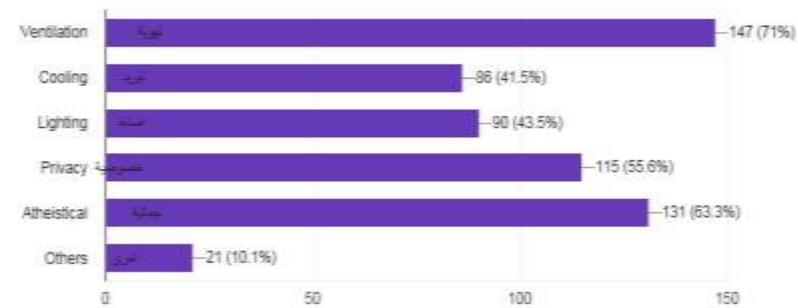
29 - Do you Know Mashrabiya(Roshan)? هل تعرف المشربية (الرواشين)؟

260 responses



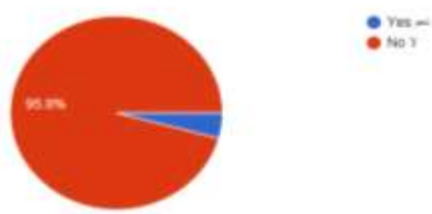
30 - If the answer of previous question is YES then what are the functions of Mashrabiya? You can choose more than one,

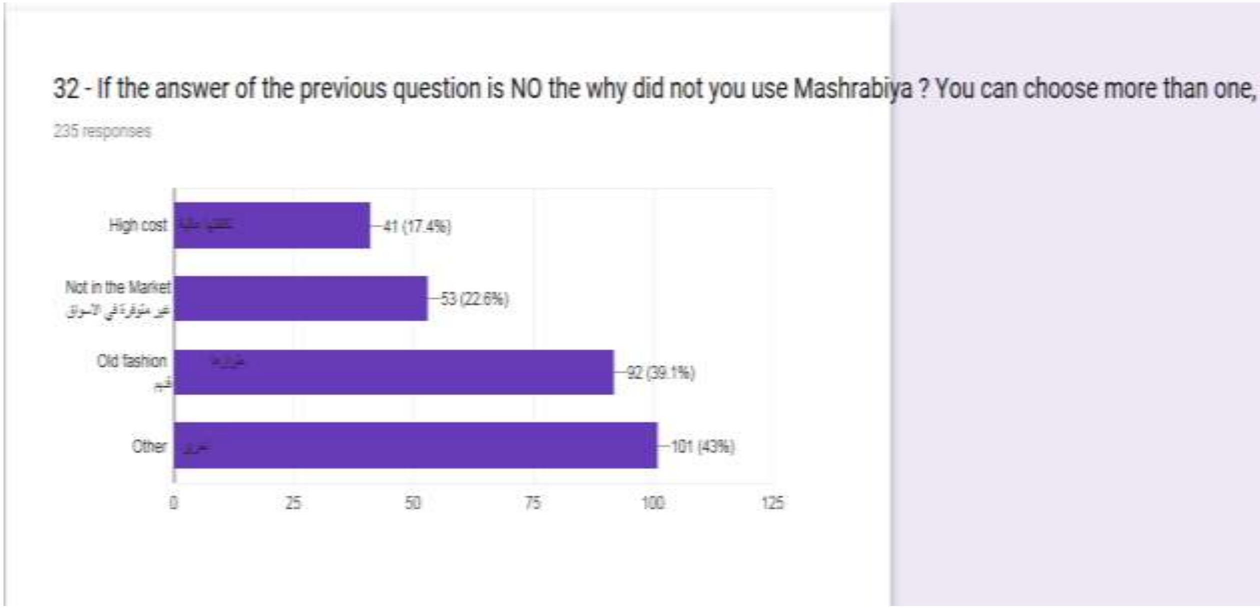
207 responses



31 - Do you use Mashrabiya in your house? هل تستخدم المشربية في مسكنك ؟

260 responses

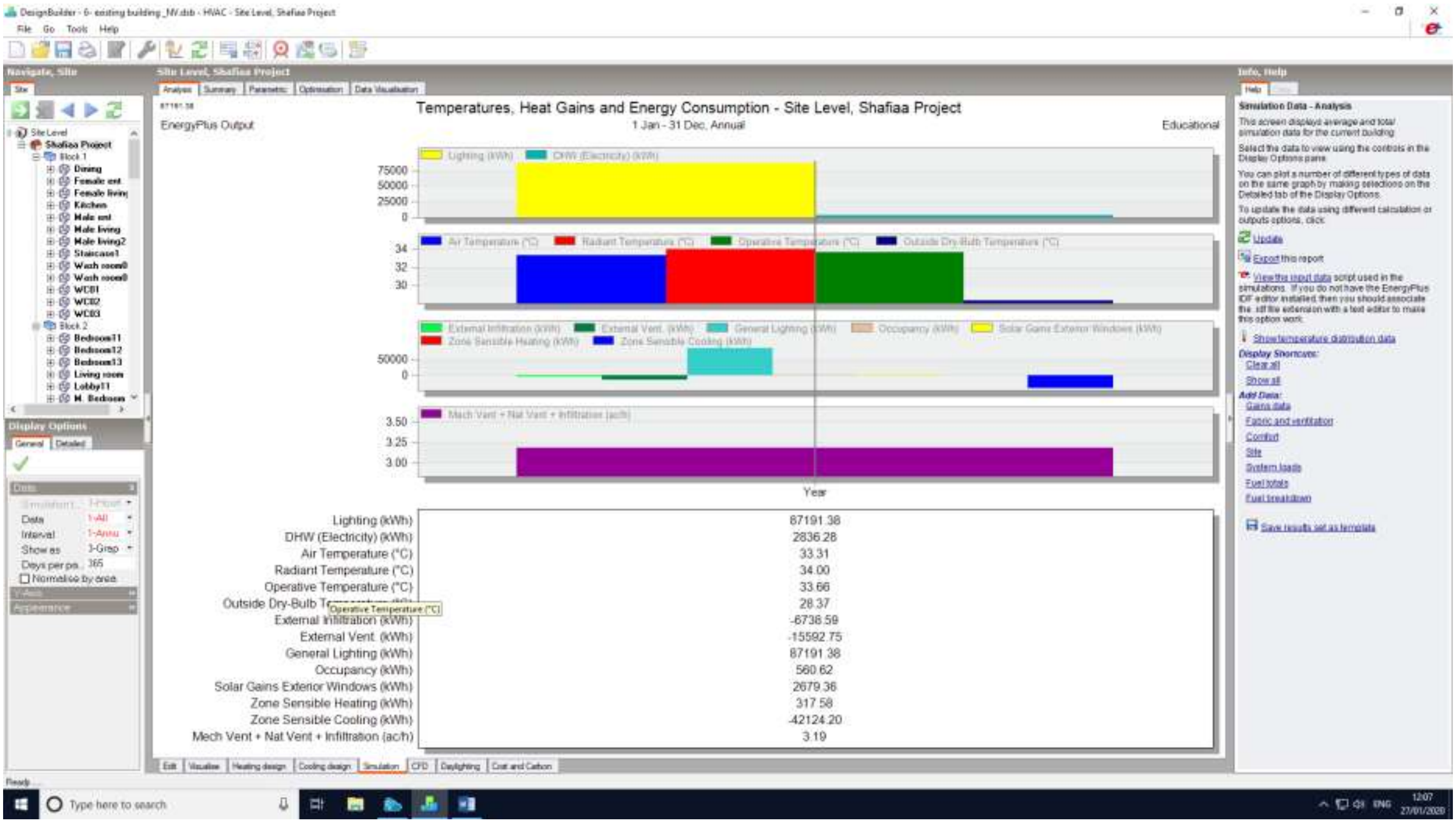


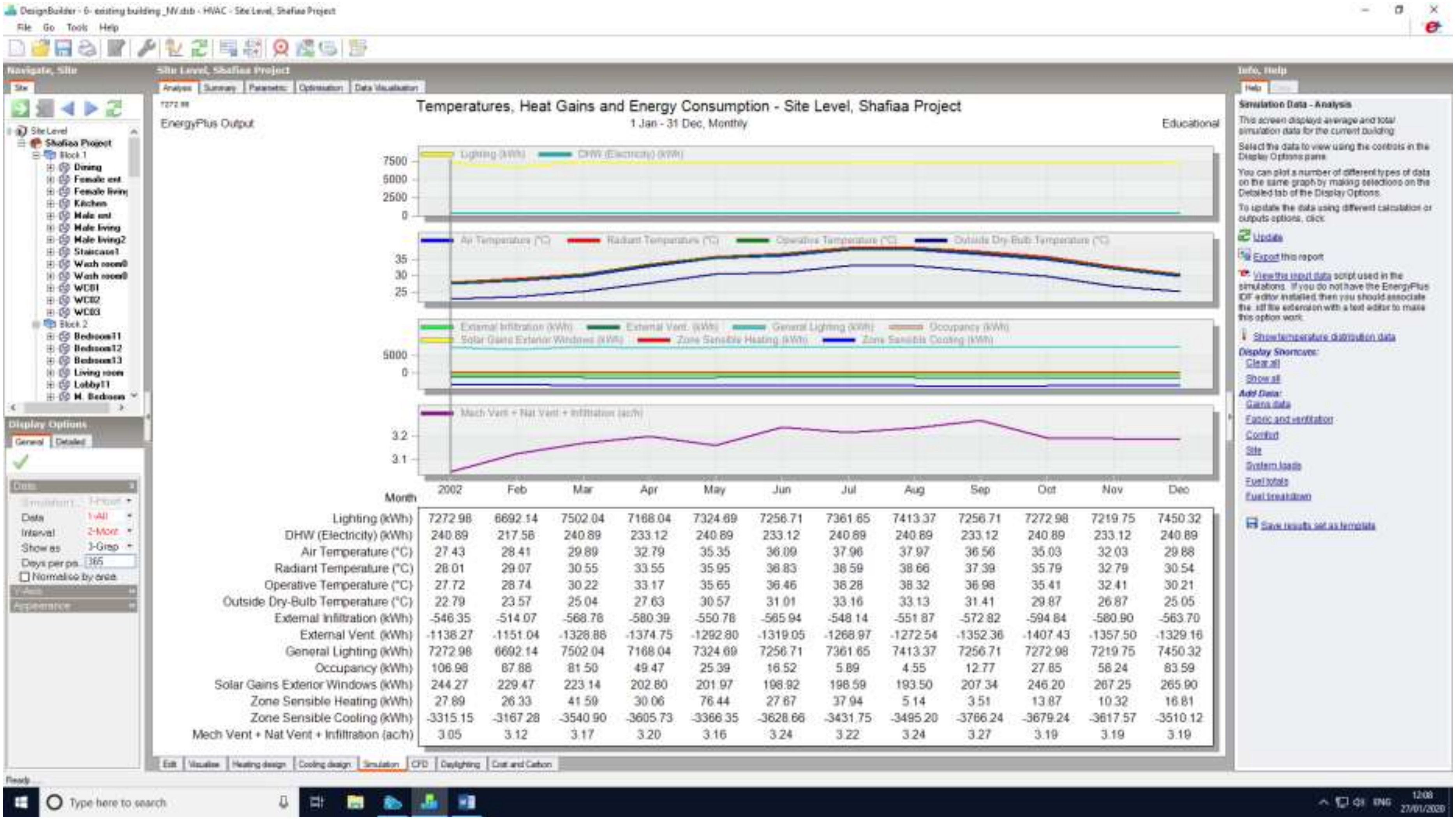

32 - If the answer of the previous question is NO the why did not you use Mashrabiya ? You can choose more than one,
235 responses
High cost
Not in the Market
Old fashion
Other
41 (17.4%)
53 (22.6%)
92 (39.1%)
101 (43%)
0
25
50
75
100
125

Simulation Results

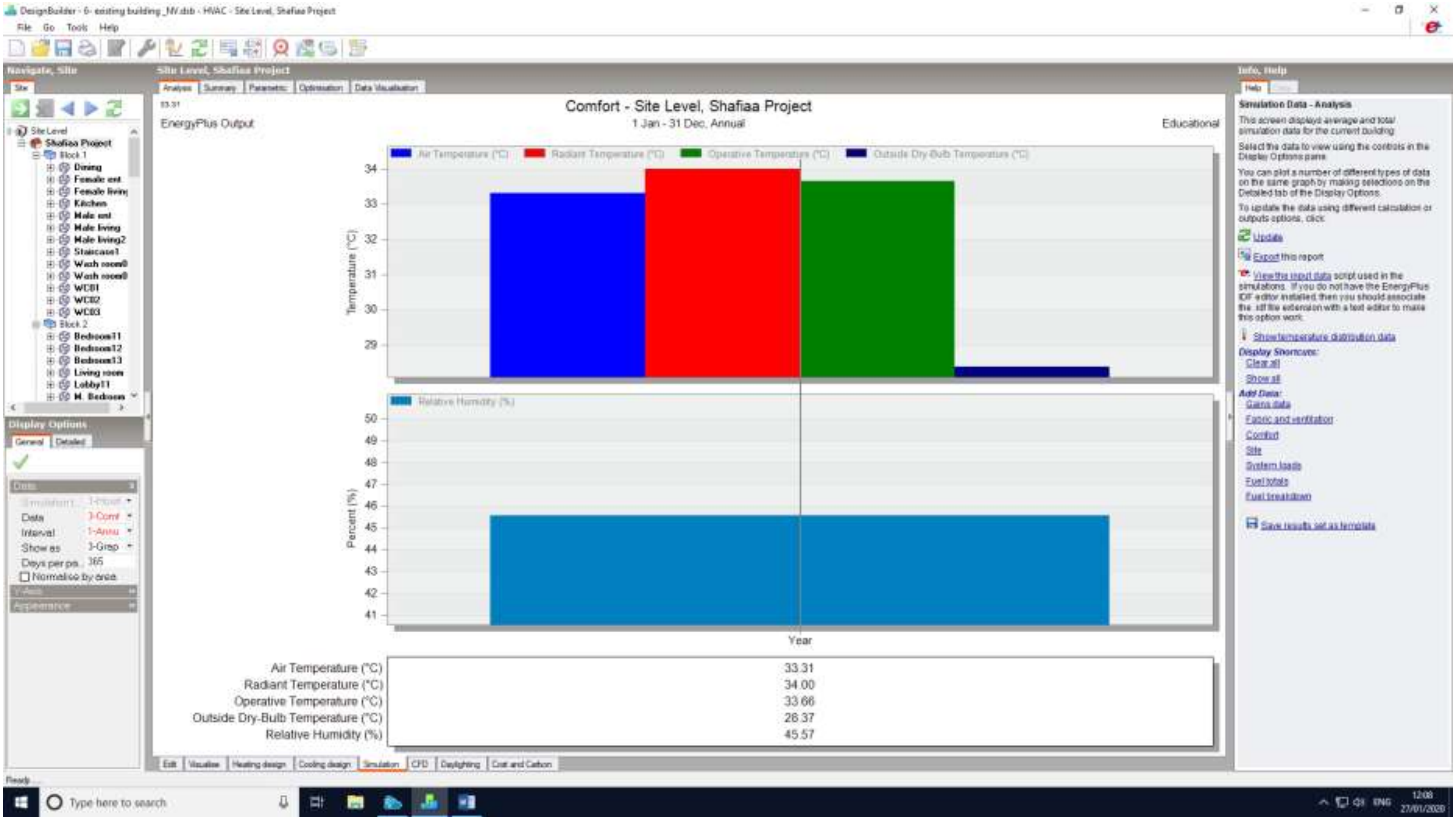
1- Existing Villa without AC
2- Wooden mashrabiya D1 without AC
3- Wooden mashrabiya D2 without AC
4- Gypsum mashrabiya D1 without AC
5- Gypsum mashrabiya D2 without AC
6- Existing Villa with AC
7- Wooden mashrabiya D1 with AC
8- Wooden mashrabiya D2 with AC
9- Gypsum mashrabiya D1 with AC
10- Gypsum mashrabiya D2 with AC

1- Existing villa without AC

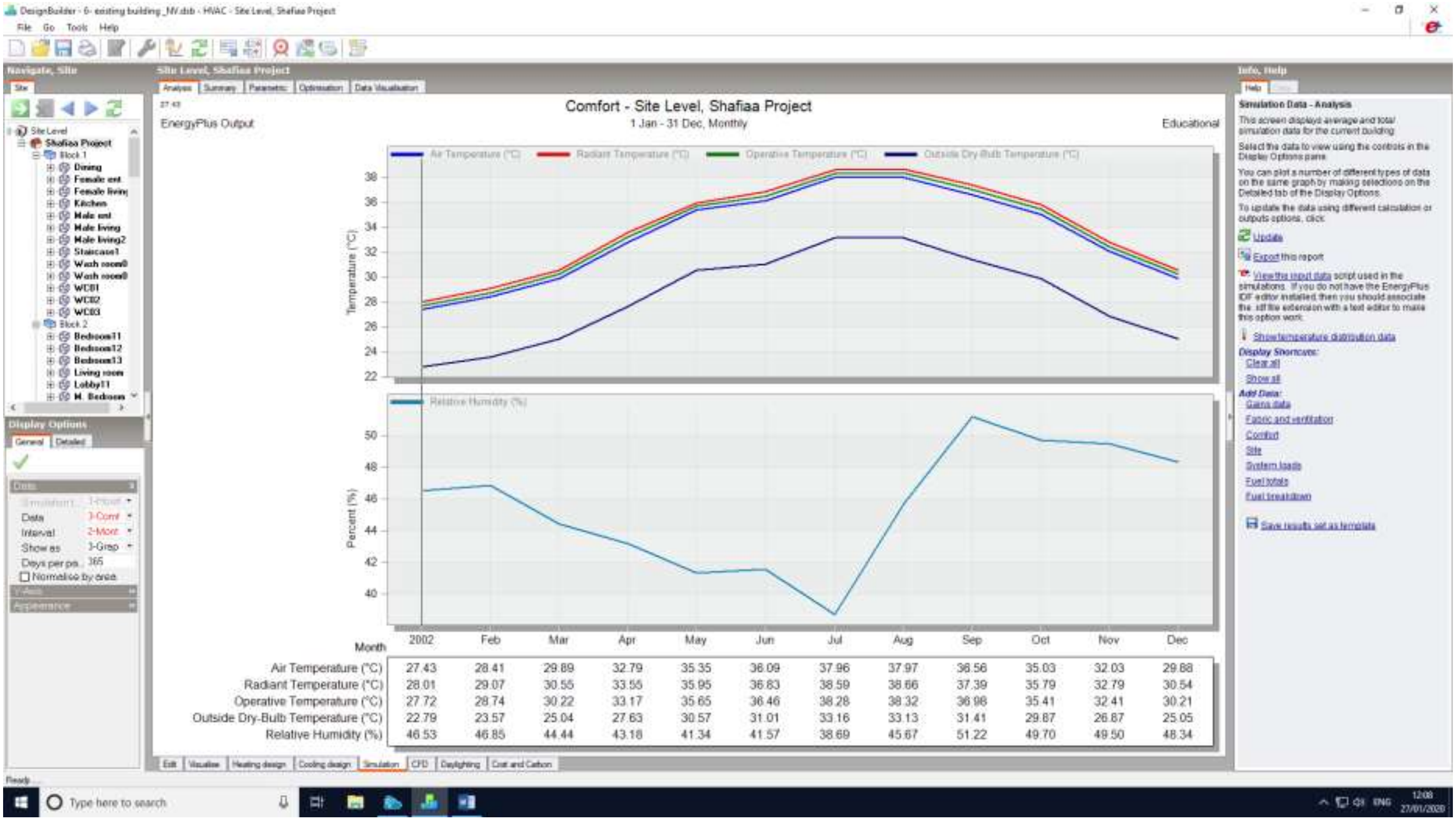


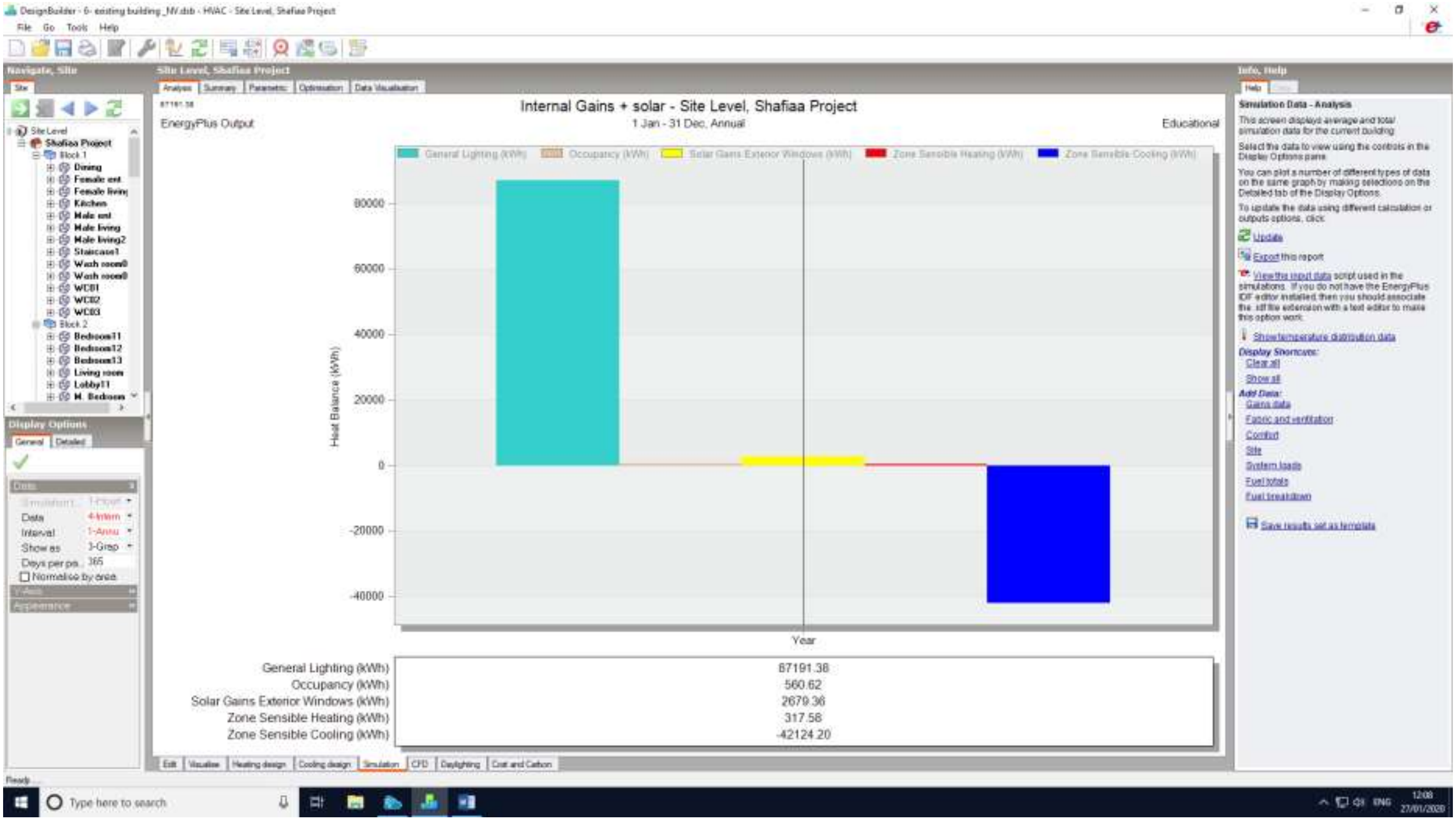


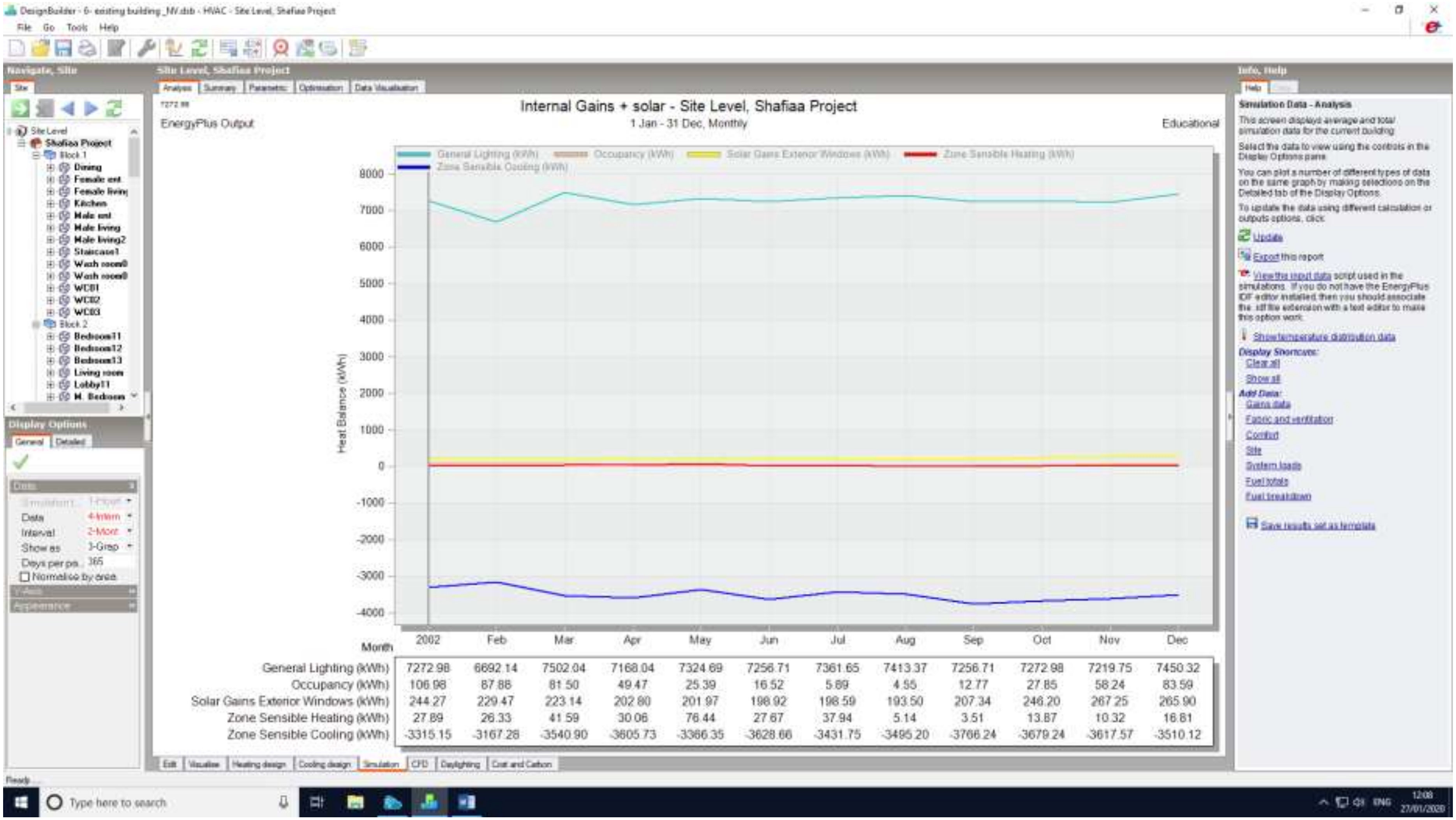
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lighting (kWh)	7272.98	6692.14	7502.04	7168.04	7324.69	7256.71	7361.65	7413.37	7256.71	7272.98	7219.75	7450.32
DHW (Electricity) (kWh)	240.89	217.56	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89
Air Temperature (°C)	27.43	28.41	29.89	32.79	35.35	36.09	37.96	37.97	36.56	35.03	32.03	29.88
Radiant Temperature (°C)	28.01	29.07	30.55	33.55	35.95	36.83	38.59	38.66	37.39	35.79	32.79	30.54
Operative Temperature (°C)	27.72	28.74	30.22	33.17	35.65	36.46	38.28	38.32	36.98	35.41	32.41	30.21
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-546.35	-514.07	-568.78	-580.39	-550.78	-565.94	-548.14	-551.87	-572.82	-594.84	-580.90	-563.70
External Vent. (kWh)	-1138.27	-1151.04	-1328.88	-1374.75	-1292.80	-1319.05	-1268.97	-1272.54	-1352.36	-1407.43	-1357.50	-1329.16
General Lighting (kWh)	7272.98	6692.14	7502.04	7168.04	7324.69	7256.71	7361.65	7413.37	7256.71	7272.98	7219.75	7450.32
Occupancy (kWh)	106.98	87.88	81.50	49.47	25.39	16.52	5.89	4.55	12.77	27.85	58.24	83.59
Solar Gains Exterior Windows (kWh)	244.27	229.47	223.14	202.80	201.97	198.92	198.59	193.50	207.34	246.20	267.25	265.90
Zone Sensible Heating (kWh)	27.89	26.33	41.59	30.06	76.44	27.67	37.94	5.14	3.51	13.87	10.32	16.81
Zone Sensible Cooling (kWh)	-3315.15	-3167.28	-3540.90	-3605.73	-3366.35	-3628.66	-3431.75	-3495.20	-3766.24	-3679.24	-3617.57	-3510.12
Mech Vent + Nat Vent + Infiltration (ac/h)	3.05	3.12	3.17	3.20	3.16	3.24	3.22	3.24	3.27	3.19	3.19	3.19



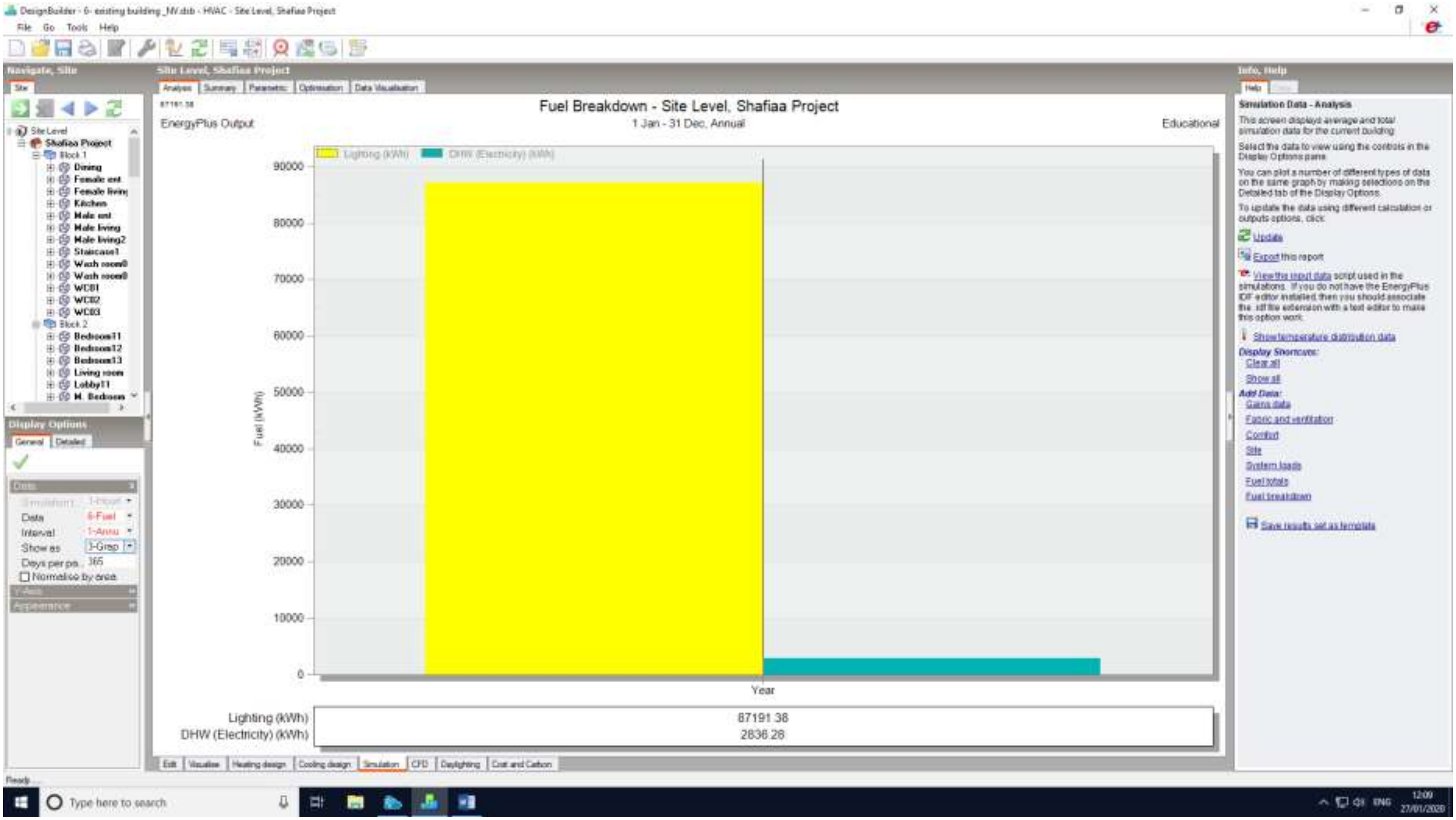
Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Temperature (°C)
Percent (%)
Year
Air Temperature (°C) 33.31
Radiant Temperature (°C) 34.00
Operative Temperature (°C) 33.66
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 45.57


DesignBuilder - 6- existing building_NV.dsb - HVAC - Site Level, Shafiaa Project
File Go Tools Help
Navigate, Site
Site Level, Shafiaa Project
Analysis Summary Parametric Optimisation Data Visualisation
Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Air Temperature (°C) 27.43 28.41 29.89 32.79 35.35 36.09 37.96 37.97 36.56 35.03 32.03 29.88
Radiant Temperature (°C) 28.01 29.07 30.55 33.55 35.95 36.83 38.59 38.66 37.39 35.79 32.79 30.54
Operative Temperature (°C) 27.72 28.74 30.22 33.17 35.65 36.46 38.28 38.32 36.98 35.41 32.41 30.21
Outside Dry-Bulb Temperature (°C) 22.79 23.57 25.04 27.63 30.57 31.01 33.16 33.13 31.41 29.87 26.87 25.05
Relative Humidity (%) 46.53 46.85 44.44 43.18 41.34 41.57 38.69 45.67 51.22 49.70 49.50 48.34
Site Level
Shafiaa Project
Block 1
Dining
Kitchen
Male living
Male living2
Staircase1
WC01
WC02
WC03
Block 2
Bedroom11
Bedroom12
Bedroom13
Living room
Lobby11
Display Options
General Detailed
Data
Interval
Show as
Normalise by area
Info, Help
Simulation Data - Analysis
This screen displays average and total simulation data for the current building
Select the data to view using the controls in the Display Options pane
Update
Export this report
Show temperature distribution data
Display Shortcuts:
Clear all
Show all
Add Data:
Gains data
Fabric and ventilation
Comfort
Site
System loads
Fuel totals
Fuel breakdown
Save results set as template
Edit Visualise Heating design Cooling design Simulation CFD Daylighting Cost and Carbon
Type here to search

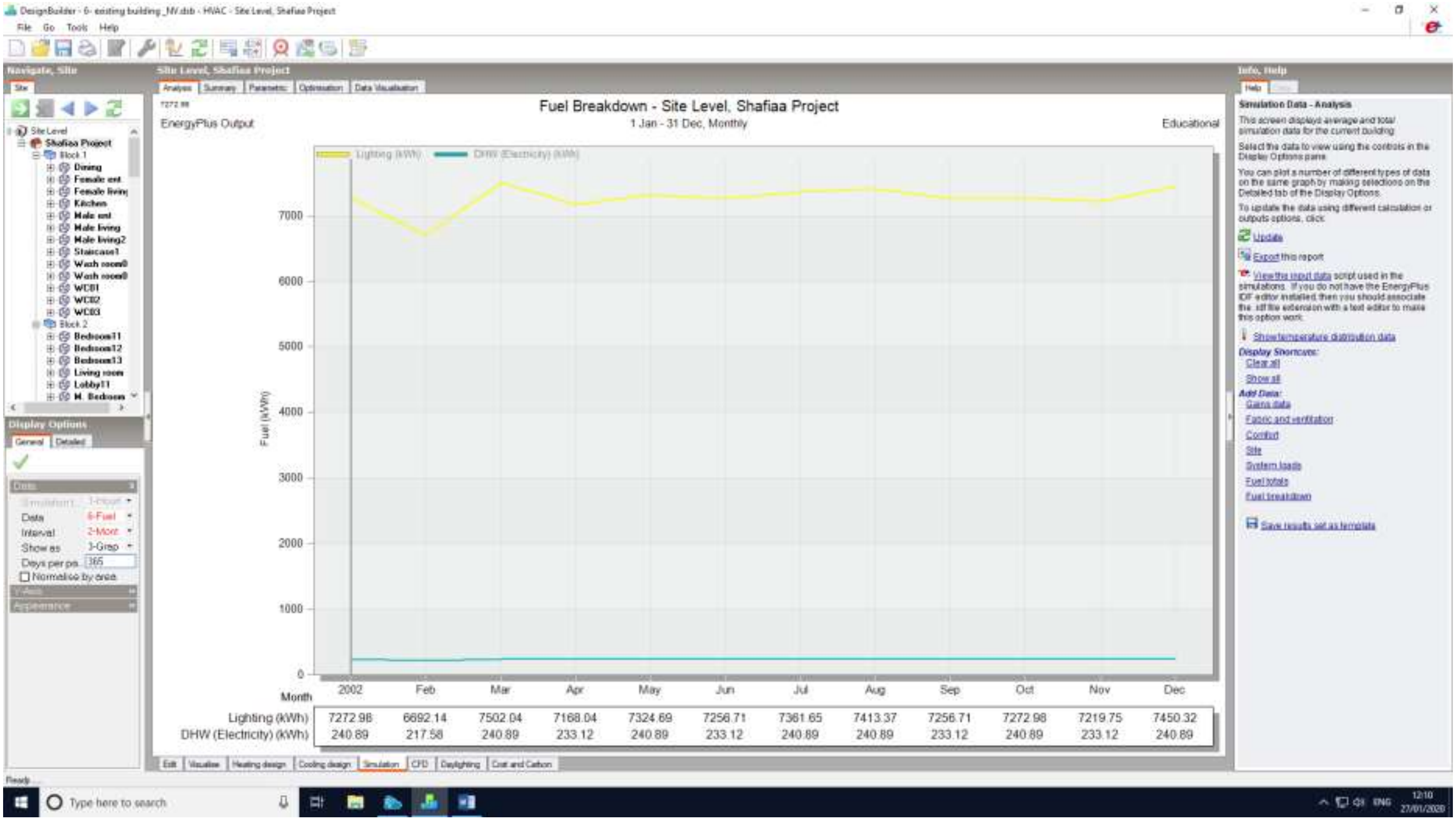

Internal Gains + solar - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Heat Balance (kWh)
Year
General Lighting (kWh) 87191.38
Occupancy (kWh) 560.62
Solar Gains Exterior Windows (kWh) 2679.36
Zone Sensible Heating (kWh) 317.58
Zone Sensible Cooling (kWh) -42124.20

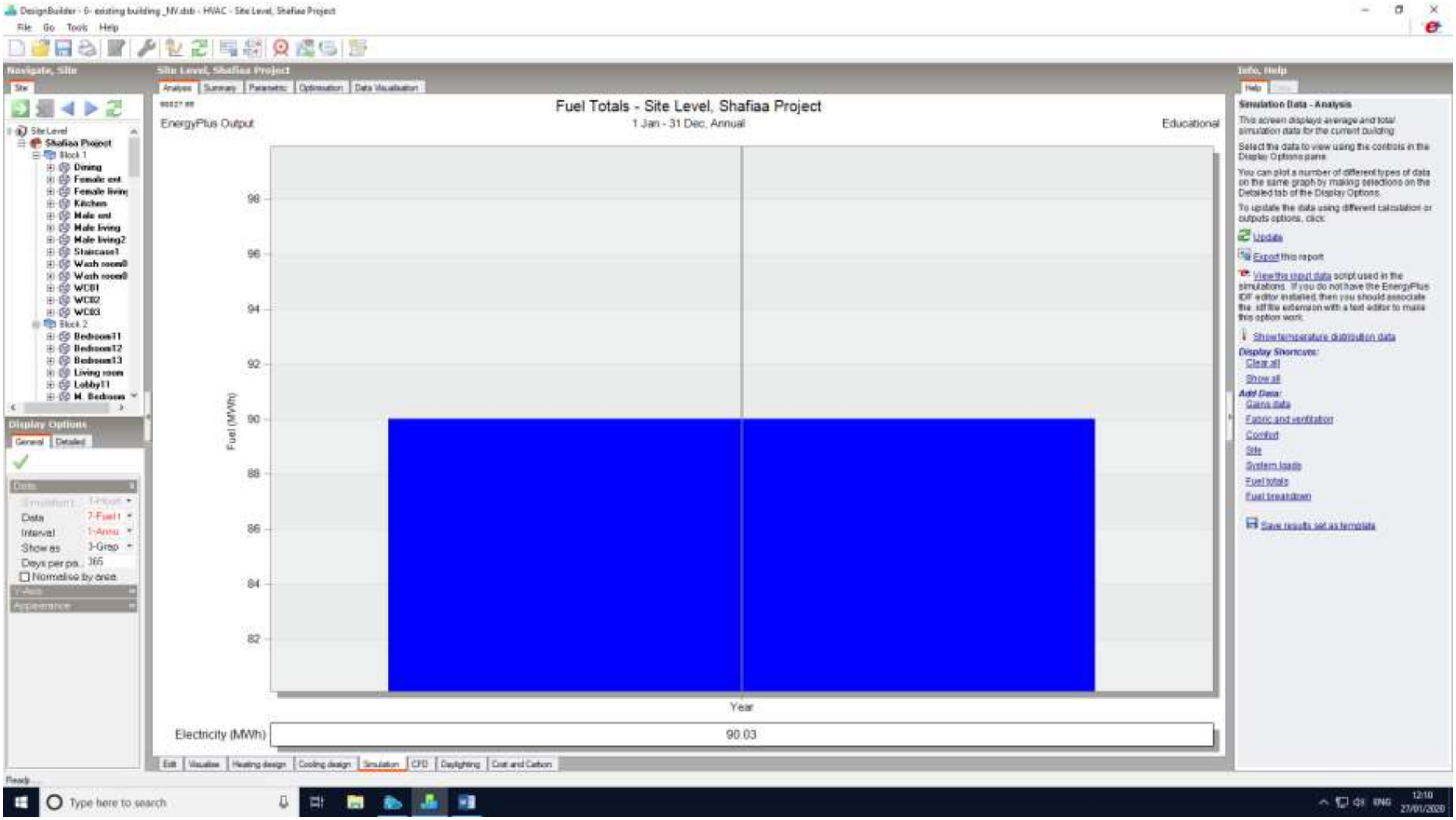


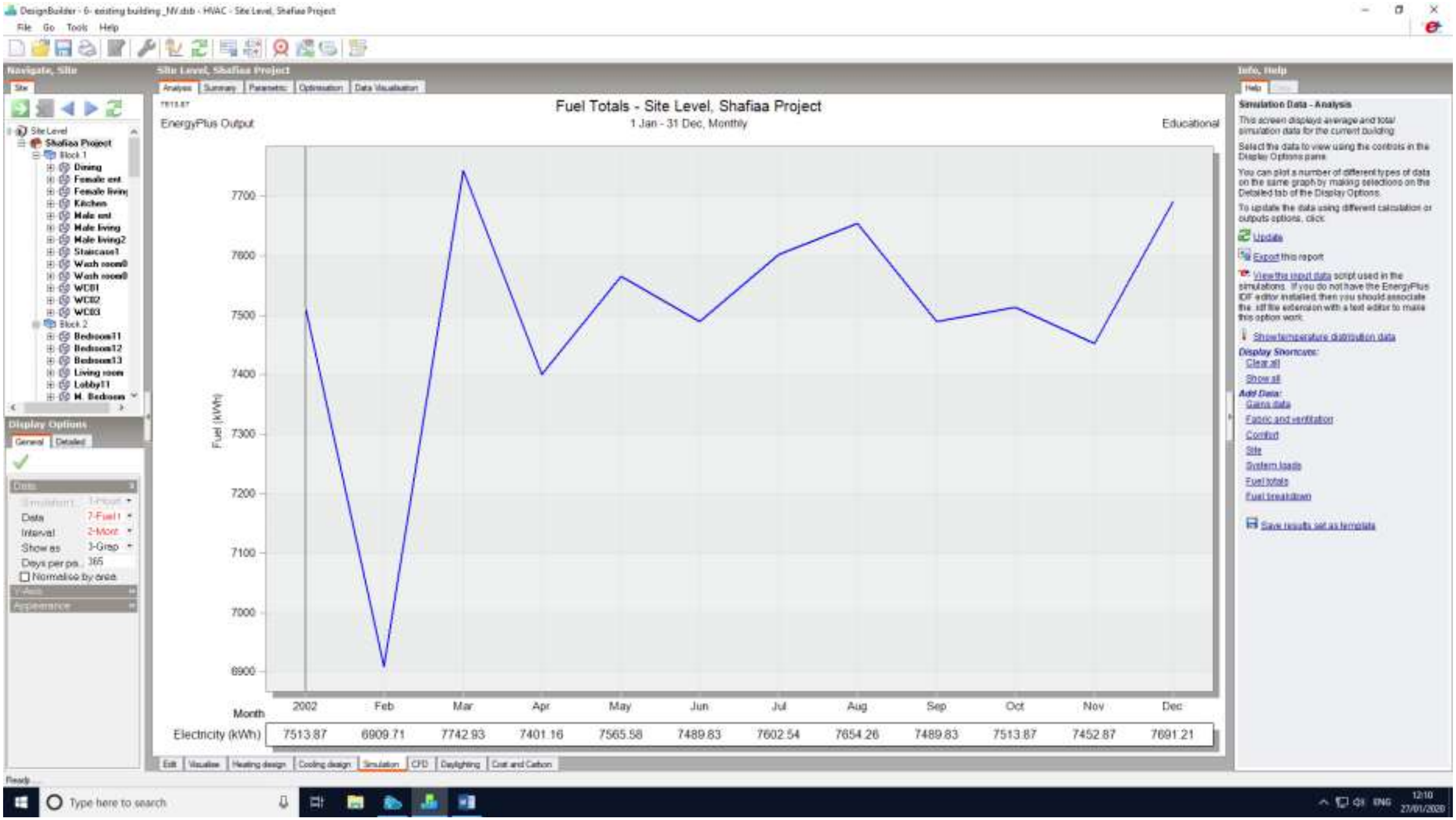
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
General Lighting (kWh)	7272.98	6692.14	7502.04	7168.04	7324.69	7256.71	7361.65	7413.37	7256.71	7272.98	7219.75	7450.32
Occupancy (kWh)	106.98	87.88	81.50	49.47	25.39	16.52	5.89	4.55	12.77	27.85	58.24	83.59
Solar Gains Exterior Windows (kWh)	244.27	229.47	223.14	202.80	201.97	198.92	198.59	193.50	207.34	246.20	267.25	265.90
Zone Sensible Heating (kWh)	27.89	26.33	41.59	30.06	76.44	27.67	37.94	5.14	3.51	13.87	10.32	16.81
Zone Sensible Cooling (kWh)	-3315.15	-3167.28	-3540.90	-3605.73	-3366.35	-3628.66	-3431.75	-3495.20	-3766.24	-3679.24	-3617.57	-3510.12

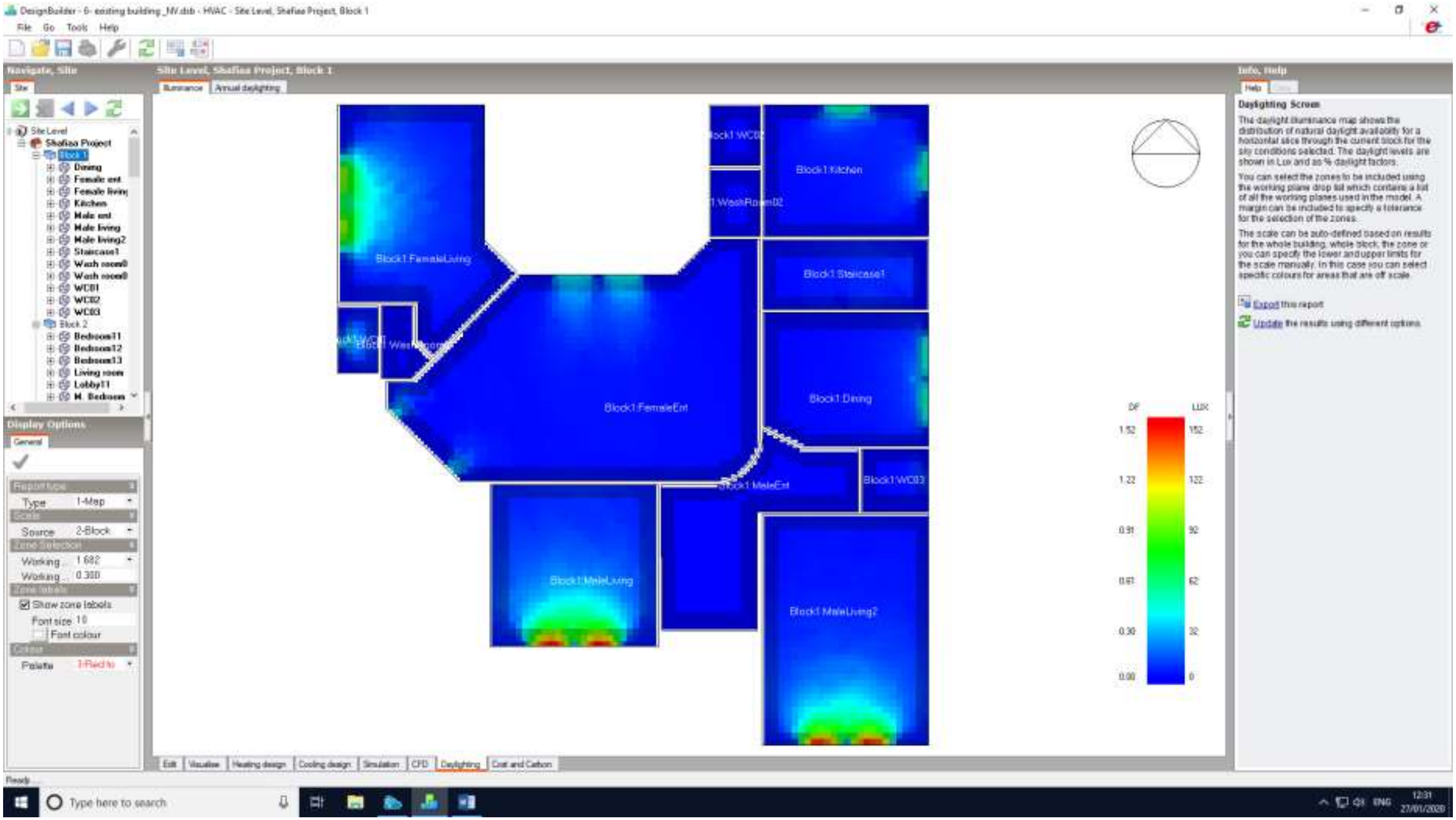


Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Fuel (kWh)
Year
Lighting (kWh) 87191.38
DHW (Electricity) (kWh) 2836.28

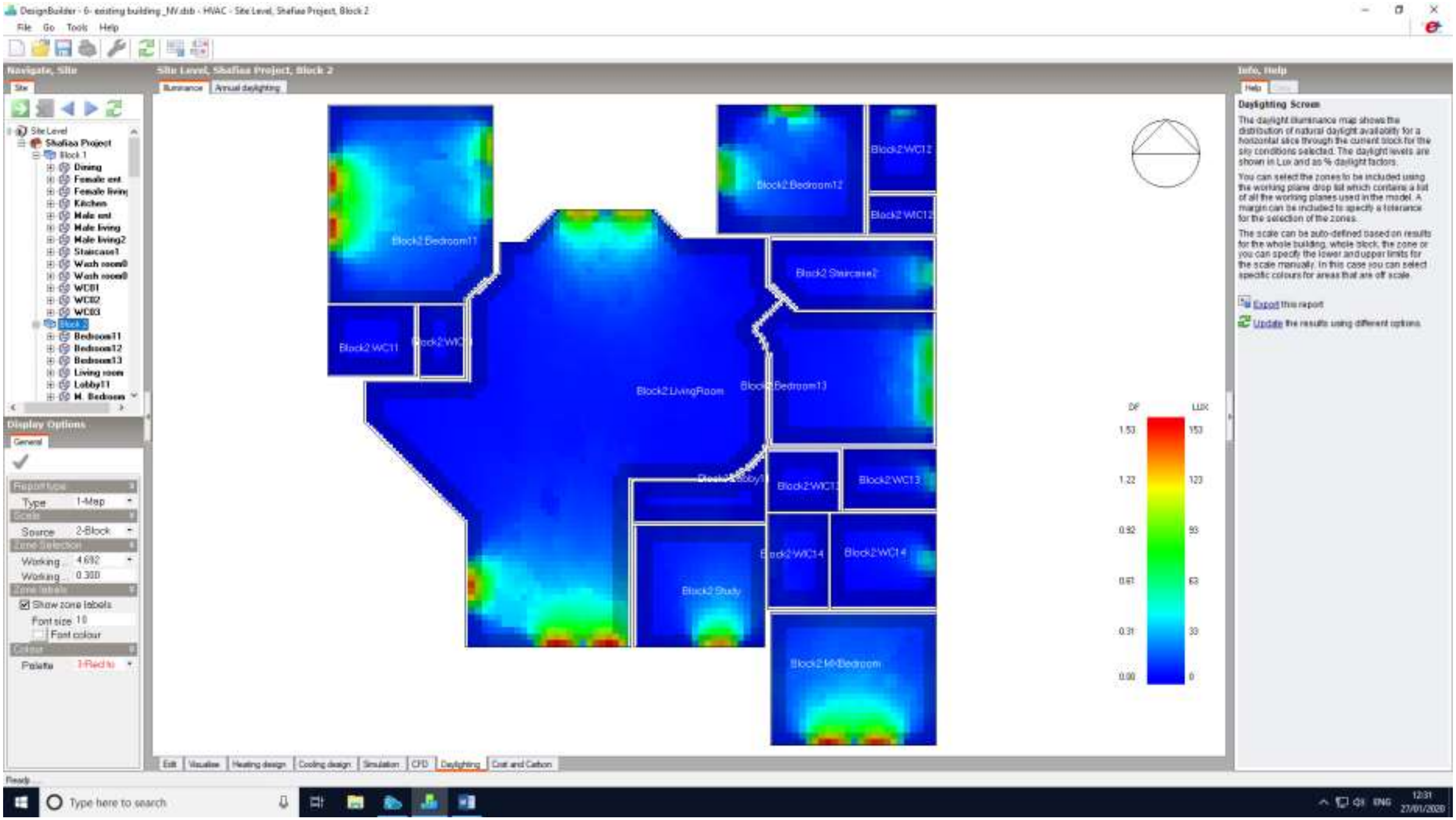

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Lighting (kWh) 7272.98 6692.14 7502.04 7168.04 7324.69 7256.71 7361.65 7413.37 7256.71 7272.98 7219.75 7450.32
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89
Simulation Data - Analysis

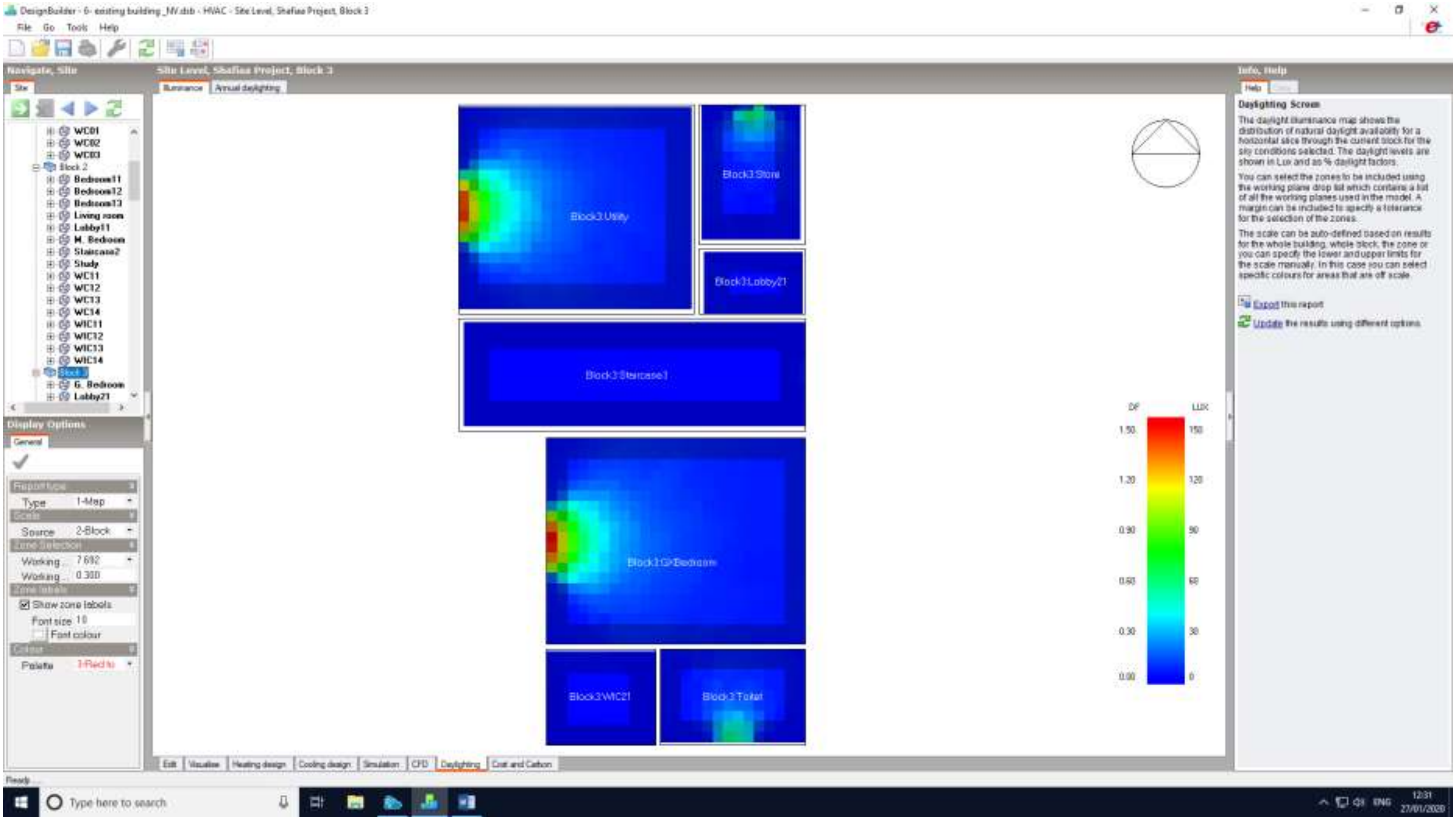

Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Fuel (MWh)
Year
Electricity (MWh)
90.03


Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
7700
7600
7500
7400
7300
7200
7100
7000
6900
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Electricity (kWh) 7513.87 6909.71 7742.93 7401.16 7565.58 7489.83 7602.54 7654.26 7489.83 7513.87 7452.87 7691.21

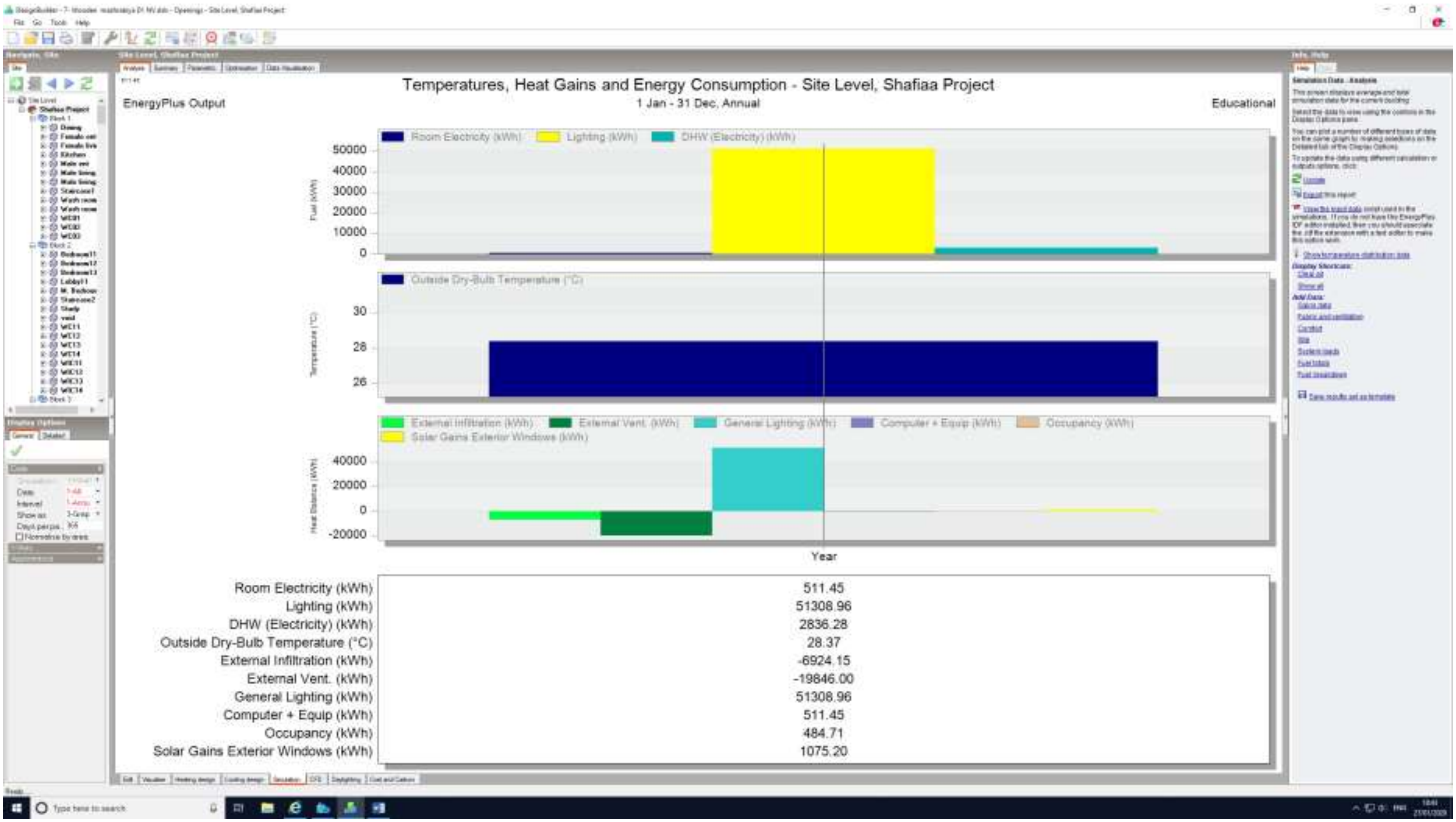


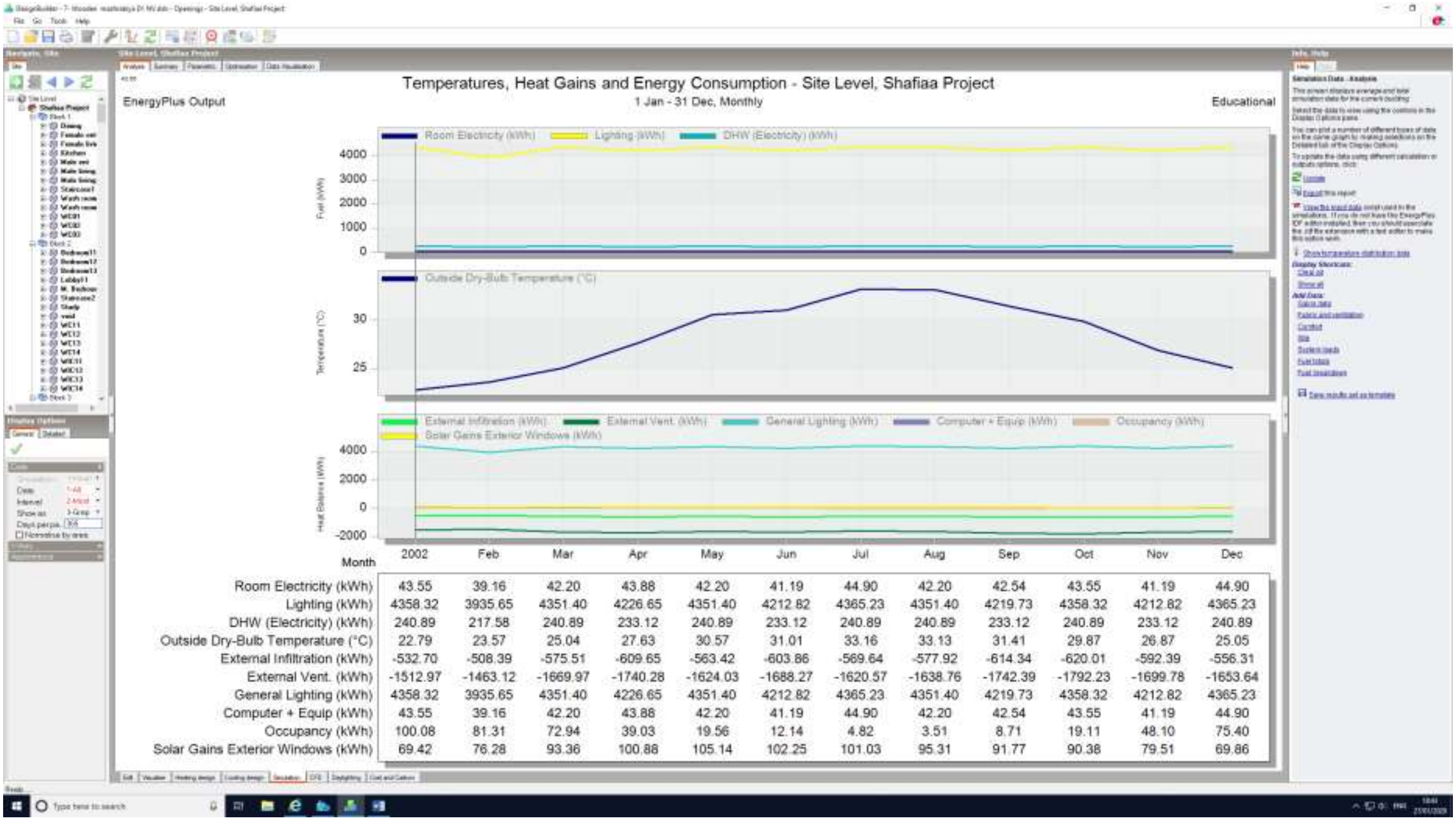
DesignBuilder - 6- existing building_NV.dsb - HVAC - Site Level, Shafiaa Project, Block 1
Site Level, Shafiaa Project, Block 1
Block1:FemaleLiving
Block1:Kitchen
Block1:Staircase1
Block1:FemaleEnt
Block1:Dining
Block1:WC03
Block1:MaleLiving
Block1:MaleLiving2
Daylighting Screen


DesignBuilder - 6- existing building _NV.dsb - HVAC - Site Level, Shafiaa Project, Block 2
Site Level, Shafiaa Project, Block 2
Daylighting Screen
Block2:Bedroom11
Block2:Bedroom12
Block2:Bedroom13
Block2:LivingRoom
Block2:Staircase2
Block2:Study
Block2:MrBedroom
DF
LUX

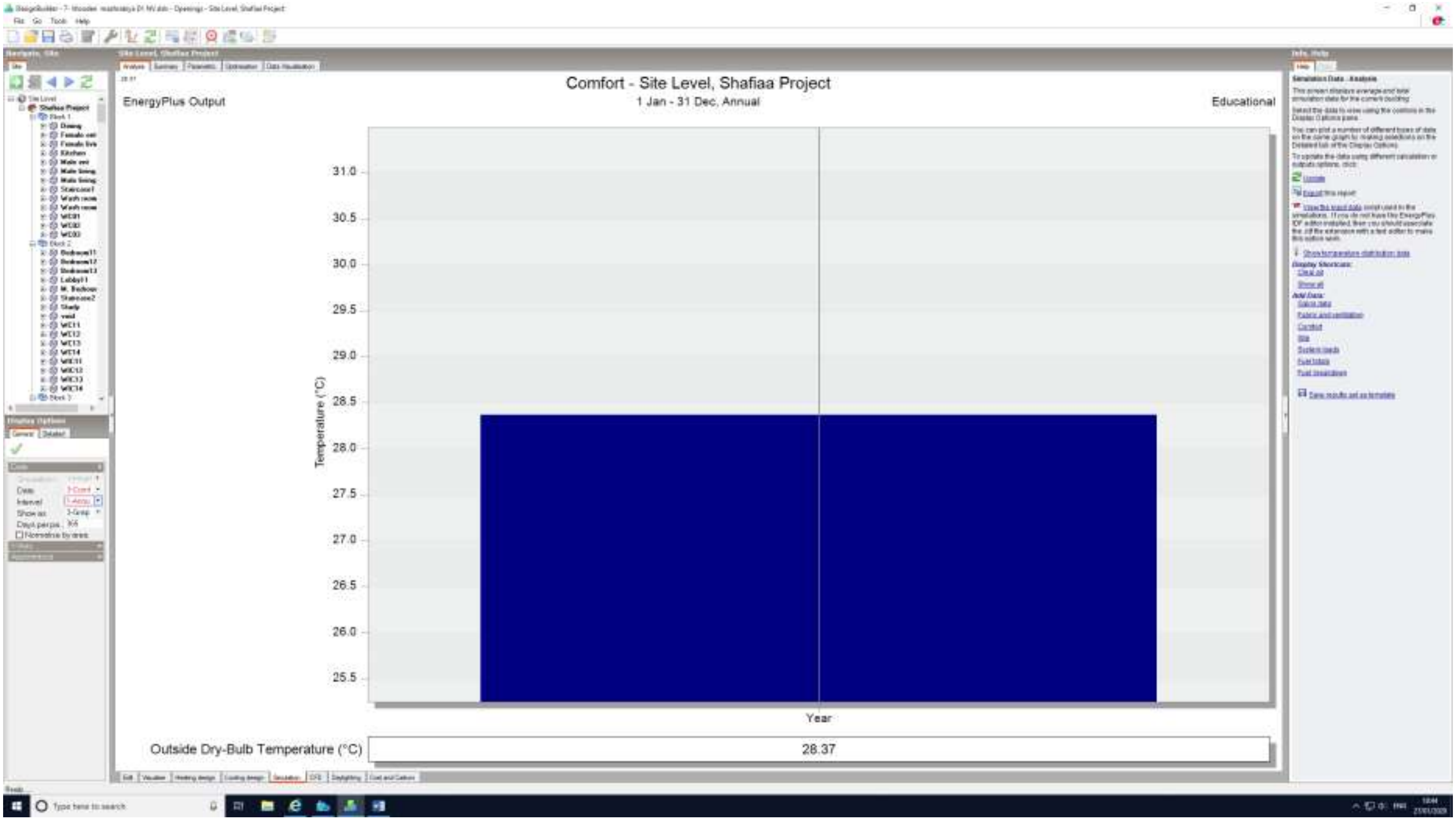

Block3:Utility
Block3:Store
Block3:Lobby21
Block3:Staircase1
Block3:G.Bedroom
Block3:WIC21
Block3:Toilet
DF
LUX
Daylighting Screen

2- Wooden mashrabiya D1 without AC

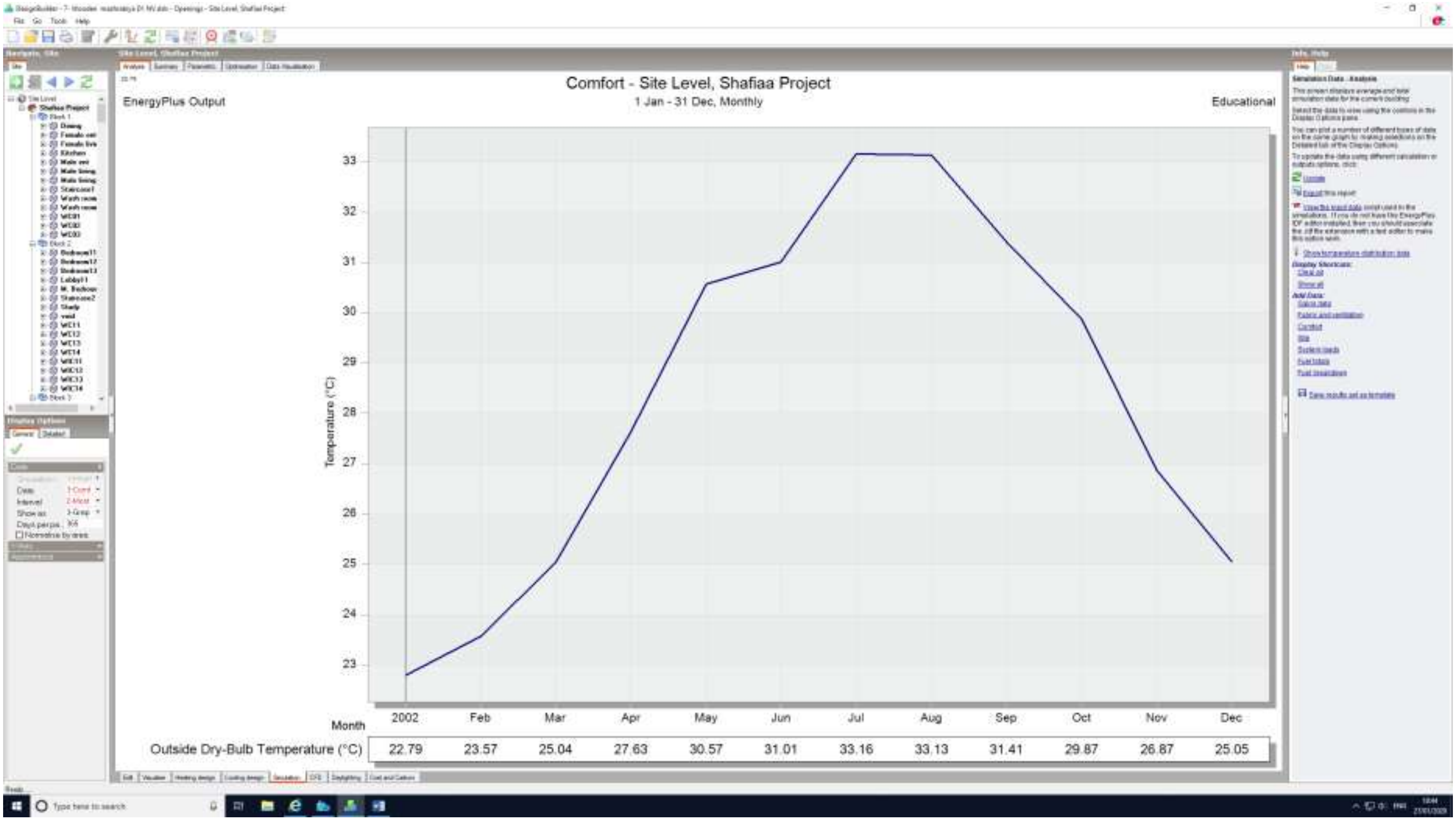


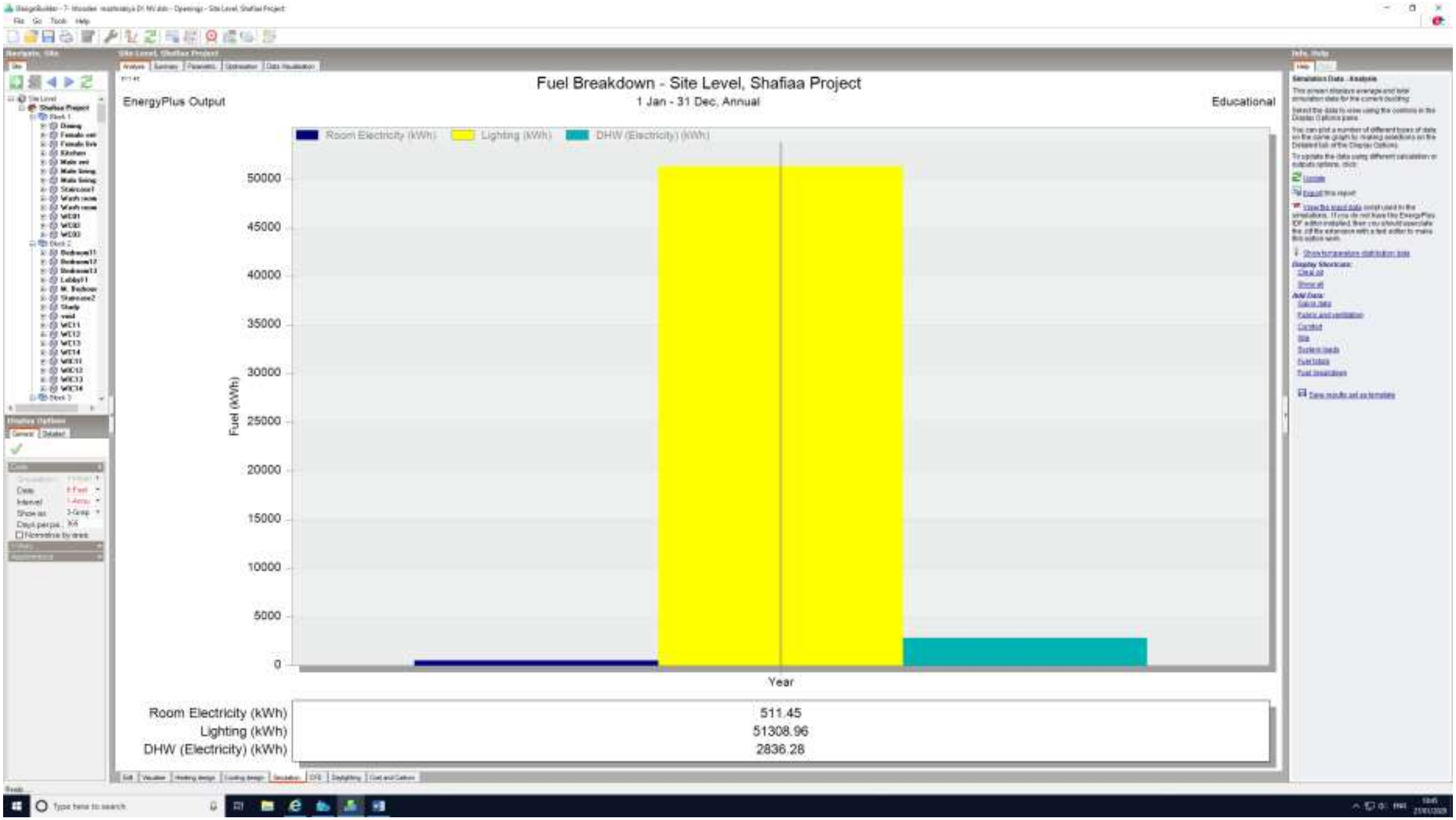


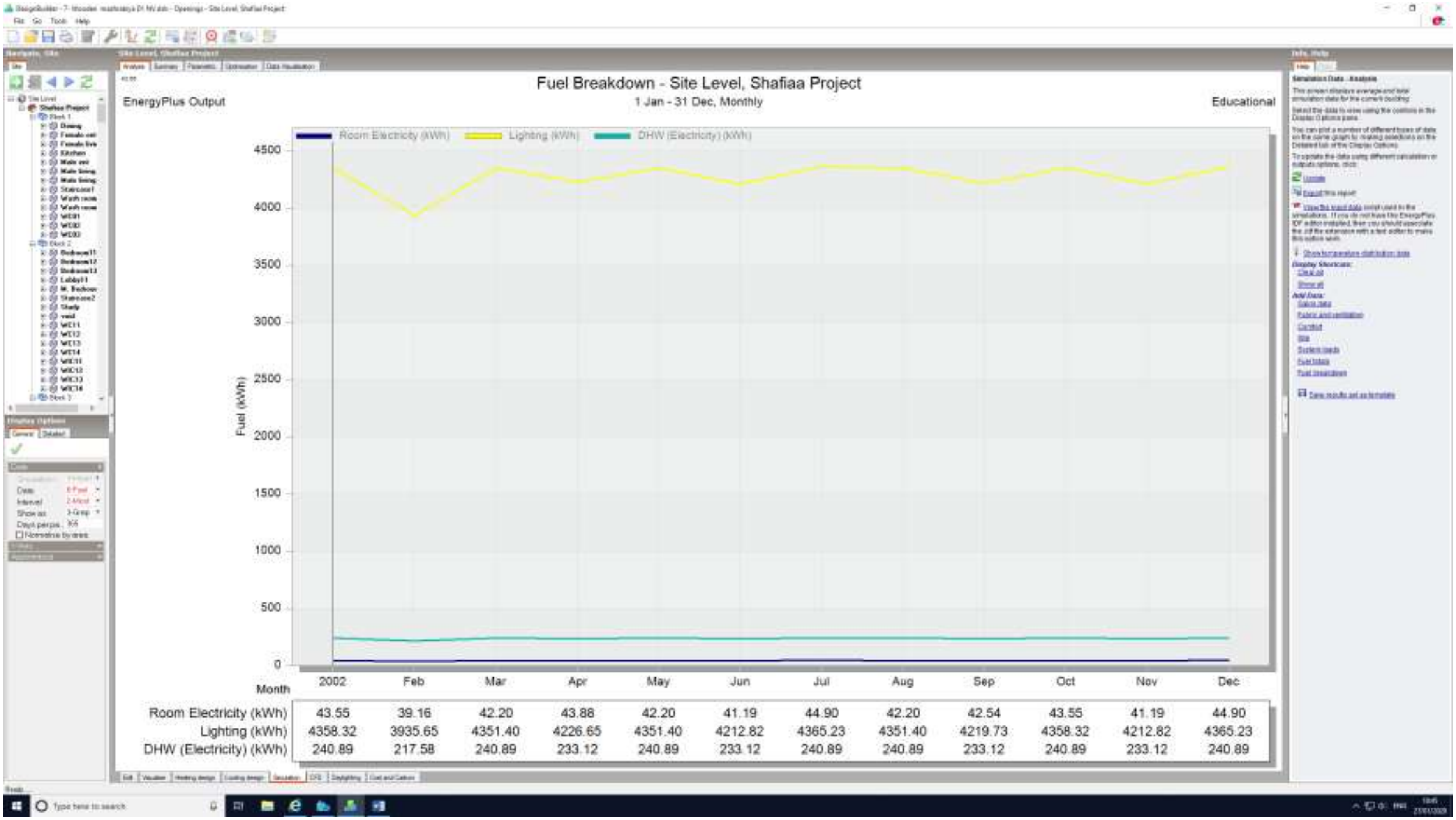
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Room Electricity (kWh)	43.55	39.16	42.20	43.88	42.20	41.19	44.90	42.20	42.54	43.55	41.19	44.90
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
DHW (Electricity) (kWh)	240.89	217.58	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-532.70	-508.39	-575.51	-609.65	-563.42	-603.86	-569.64	-577.92	-614.34	-620.01	-592.39	-556.31
External Vent. (kWh)	-1512.97	-1463.12	-1669.97	-1740.28	-1624.03	-1688.27	-1620.57	-1638.76	-1742.39	-1792.23	-1699.78	-1653.64
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Computer + Equip (kWh)	43.55	39.16	42.20	43.88	42.20	41.19	44.90	42.20	42.54	43.55	41.19	44.90
Occupancy (kWh)	100.08	81.31	72.94	39.03	19.56	12.14	4.82	3.51	8.71	19.11	48.10	75.40
Solar Gains Exterior Windows (kWh)	69.42	76.28	93.36	100.88	105.14	102.25	101.03	95.31	91.77	90.38	79.51	69.86

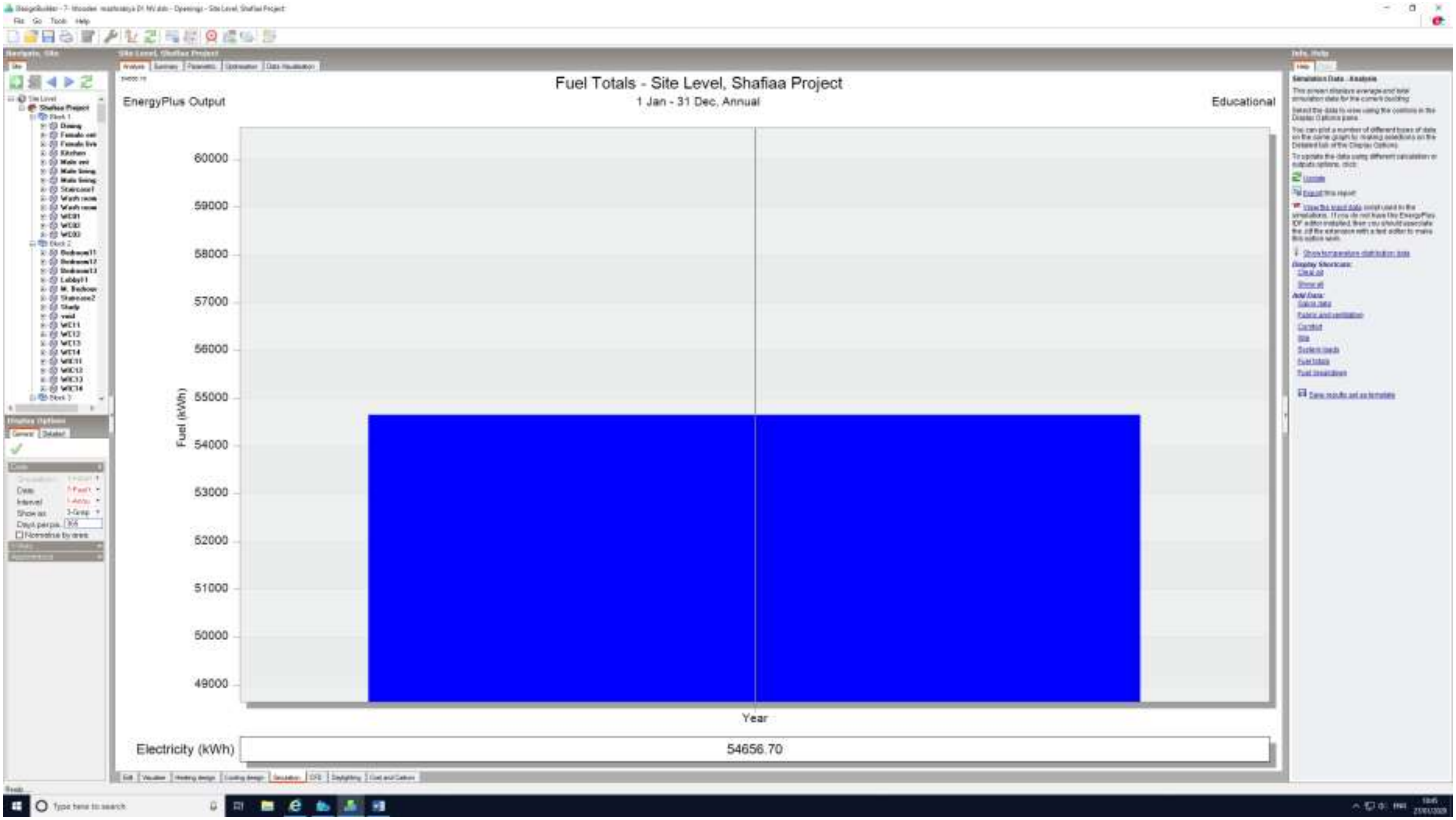


Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
31.0
30.5
30.0
29.5
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5
Temperature (°C)
Year
Outside Dry-Bulb Temperature (°C)
28.37

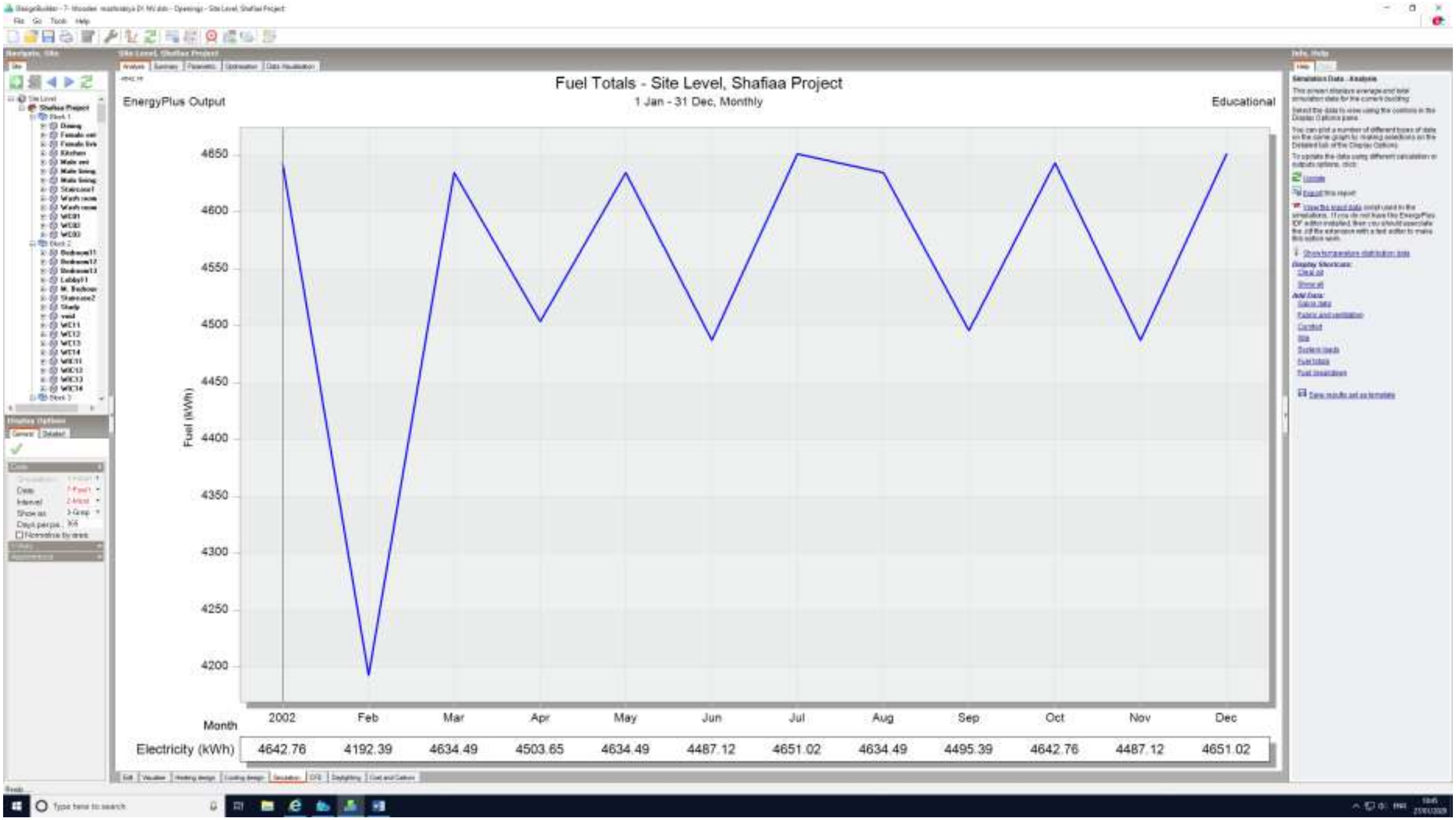

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Temperature (°C)
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Outside Dry-Bulb Temperature (°C)
22.79
23.57
25.04
27.63
30.57
31.01
33.16
33.13
31.41
29.87
26.87
25.05

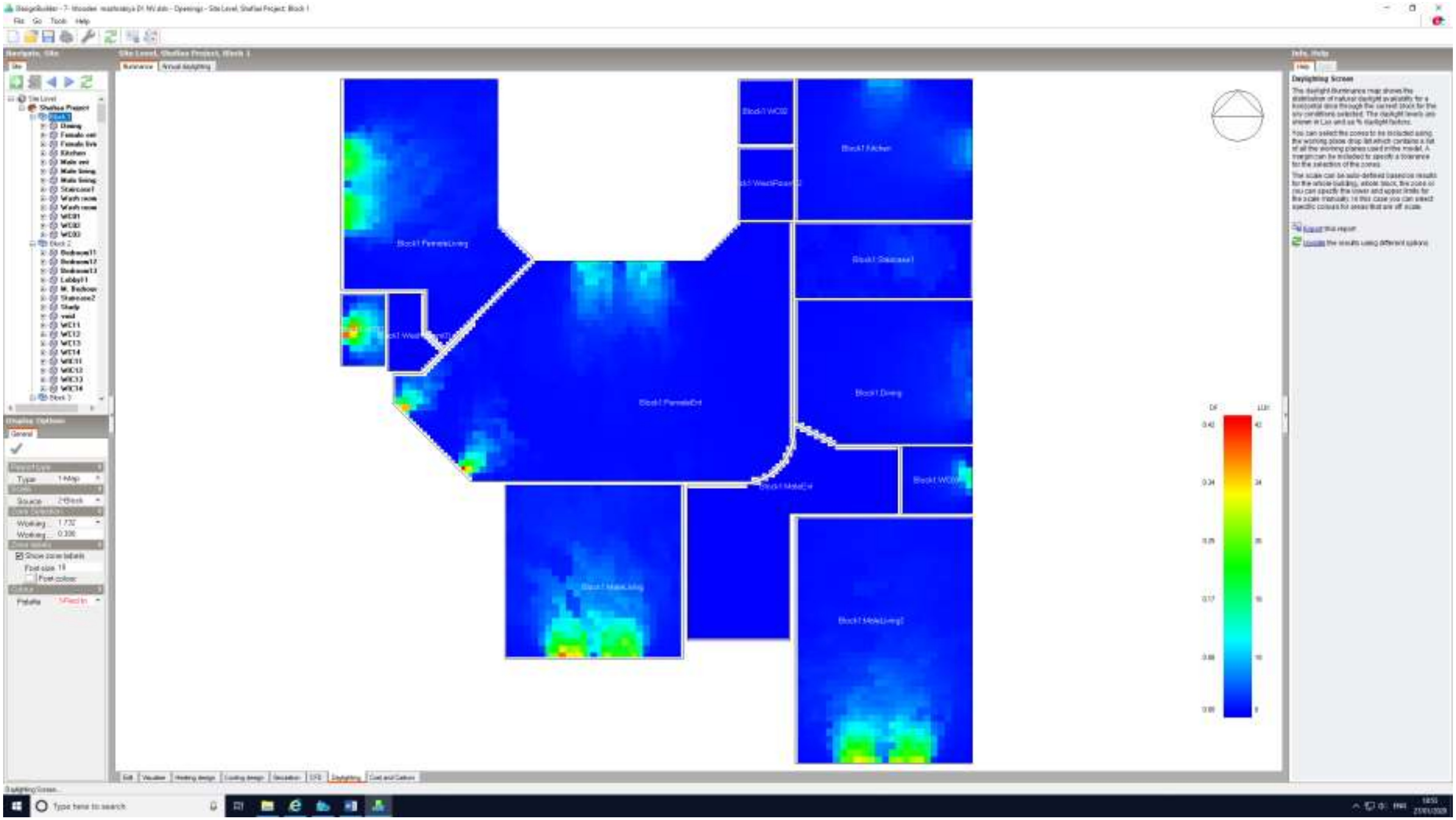

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Room Electricity (kWh)
Lighting (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Year
Room Electricity (kWh) 511.45
Lighting (kWh) 51308.96
DHW (Electricity) (kWh) 2836.28

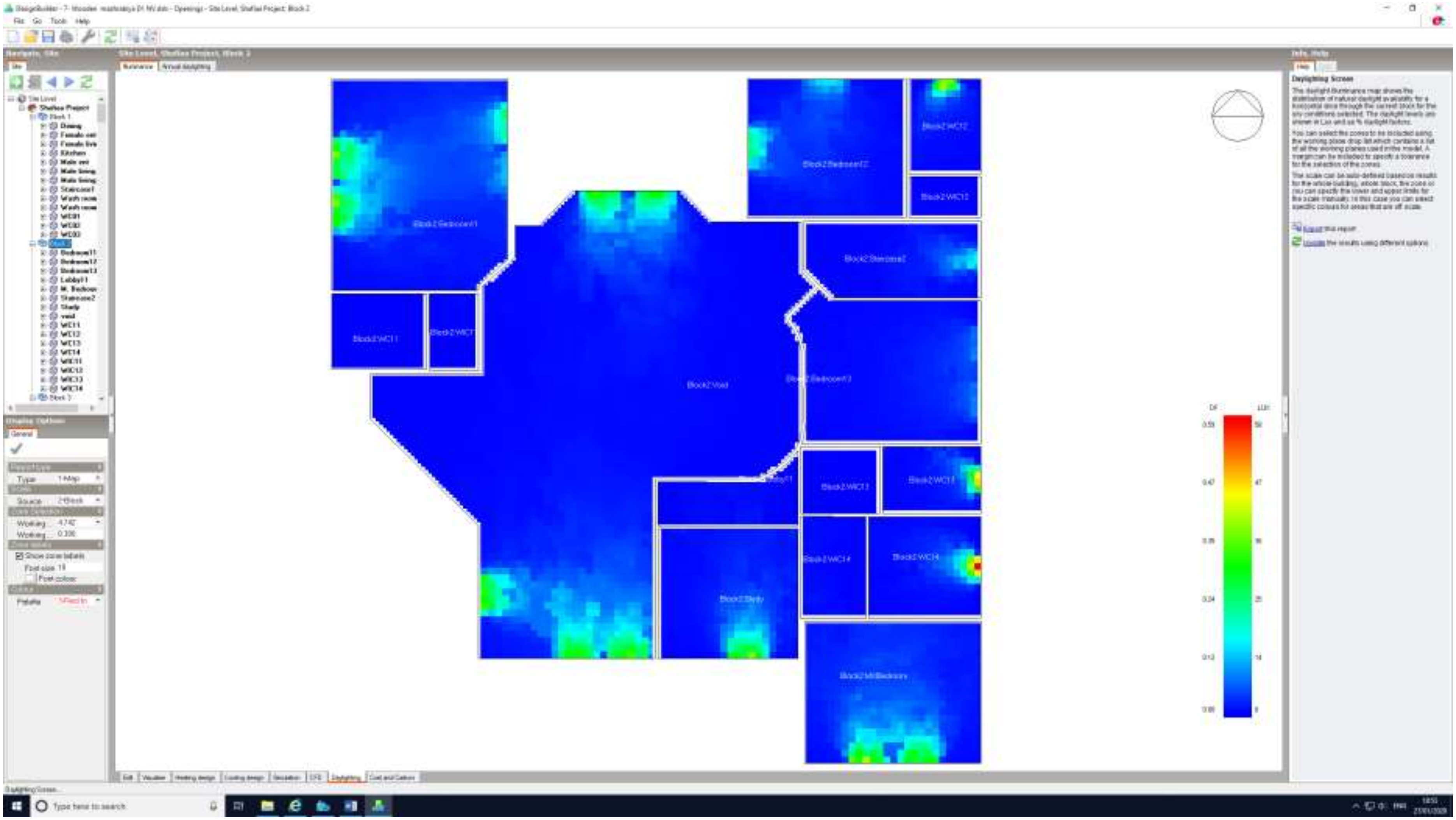

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Room Electricity (kWh)
Lighting (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Room Electricity (kWh) 43.55 39.16 42.20 43.88 42.20 41.19 44.90 42.20 42.54 43.55 41.19 44.90
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89

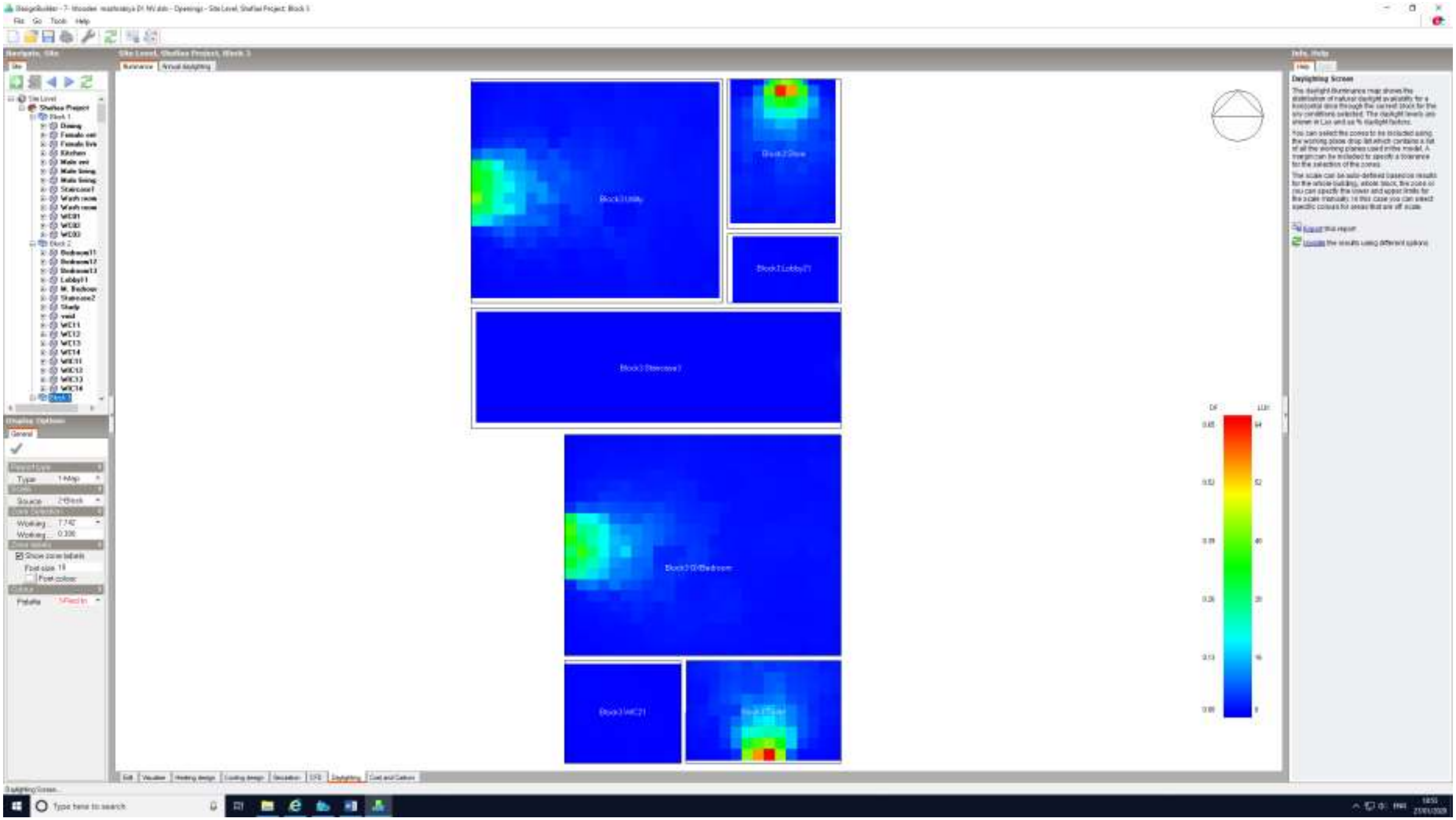


Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
60000
59000
58000
57000
56000
55000
54000
53000
52000
51000
50000
49000
Fuel (kWh)
Year
Electricity (kWh)
54656.70

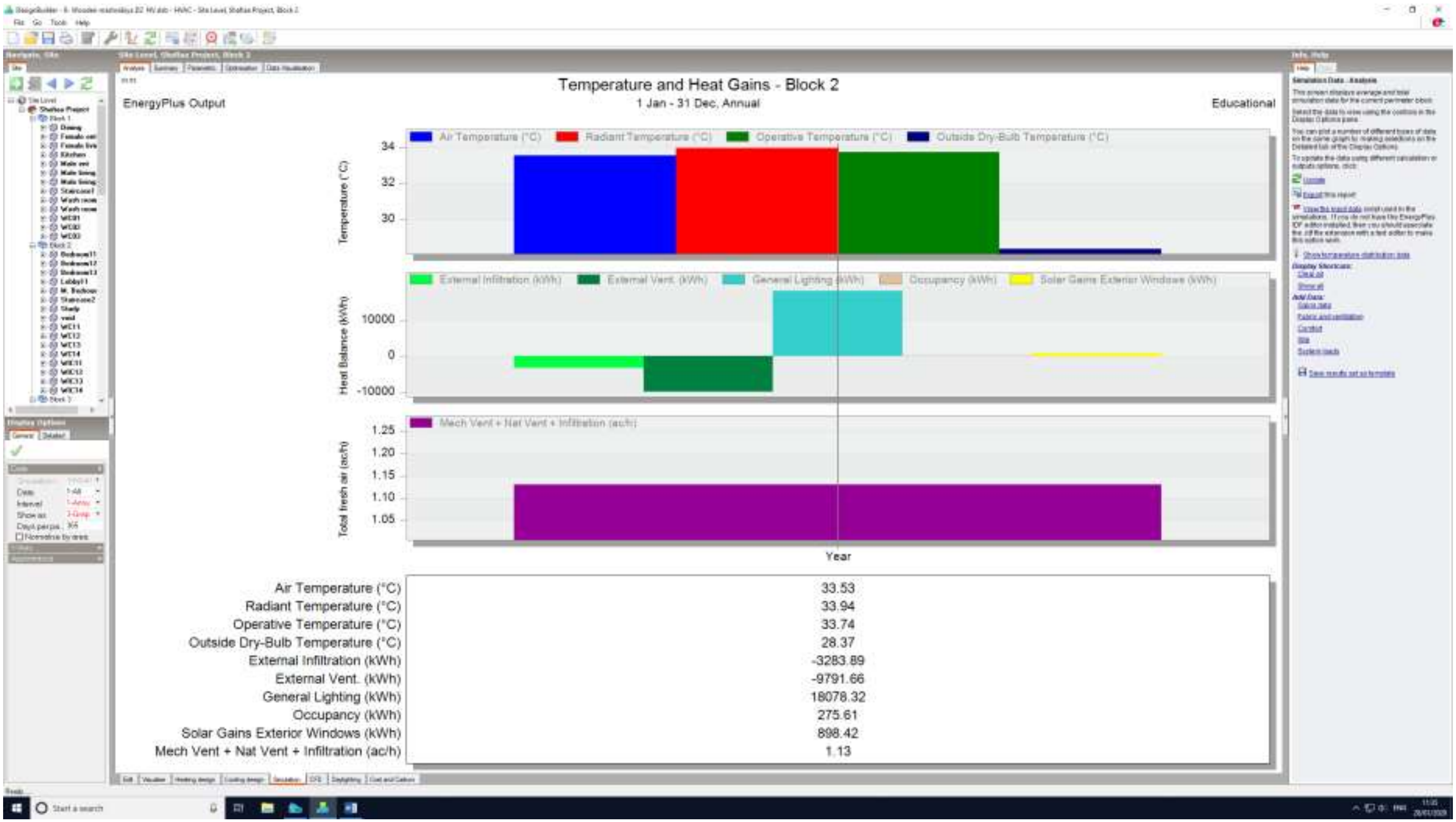

Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
4650
4600
4550
4500
4450
4400
4350
4300
4250
4200
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Electricity (kWh)
4642.76
4192.39
4634.49
4503.65
4634.49
4487.12
4651.02
4634.49
4495.39
4642.76
4487.12
4651.02

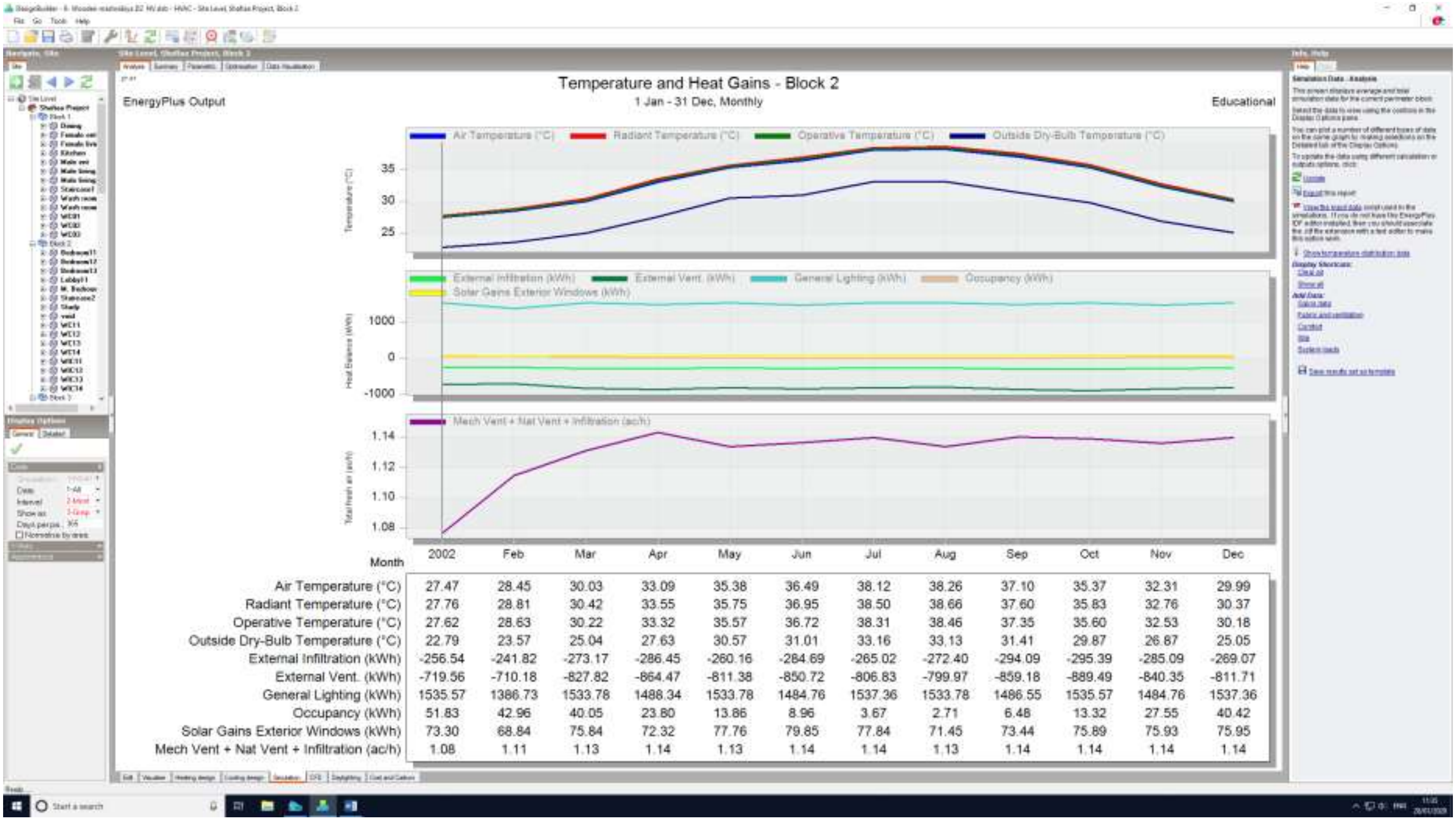




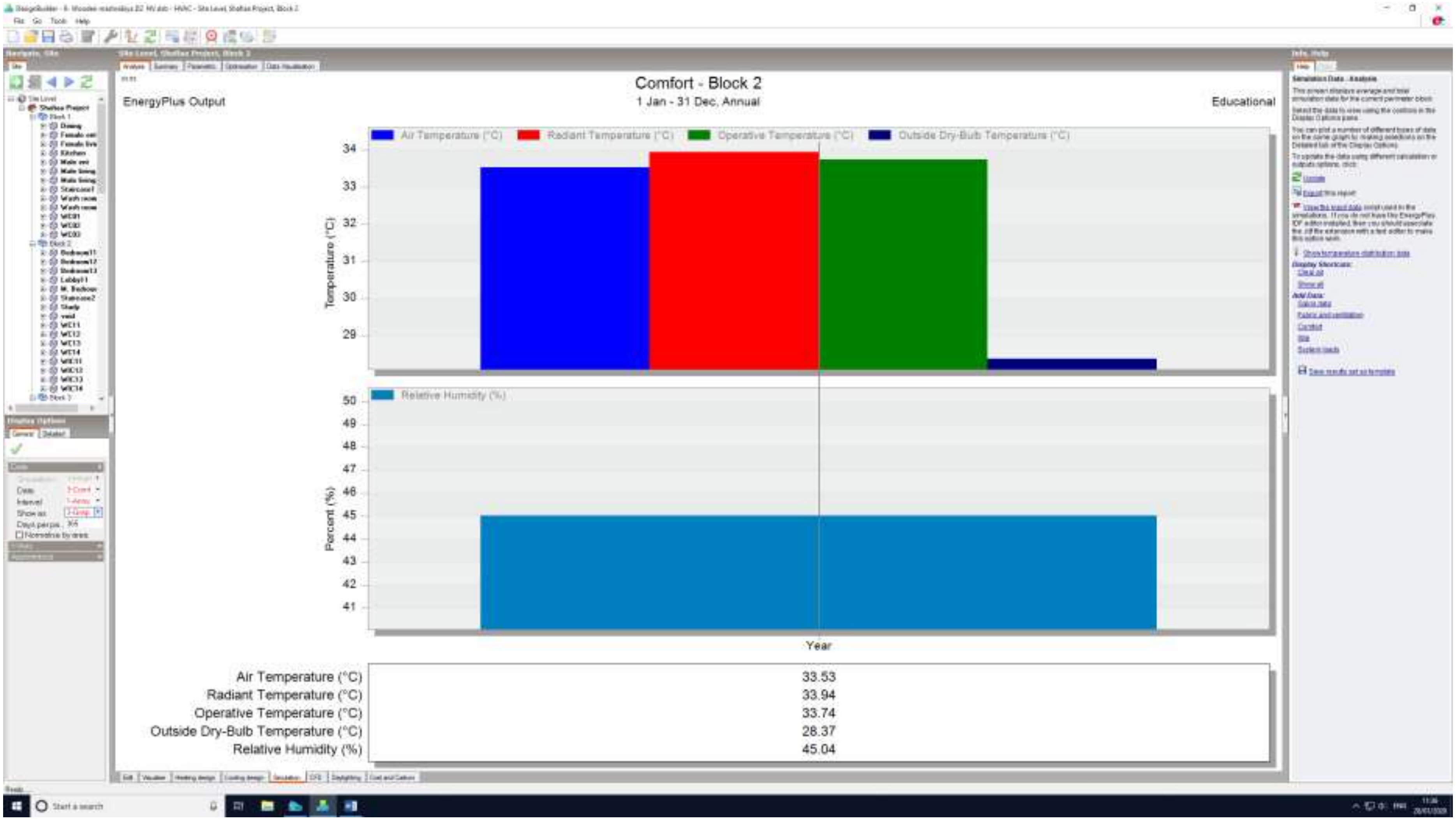


3- Wooden mashrabiya D2 without AC

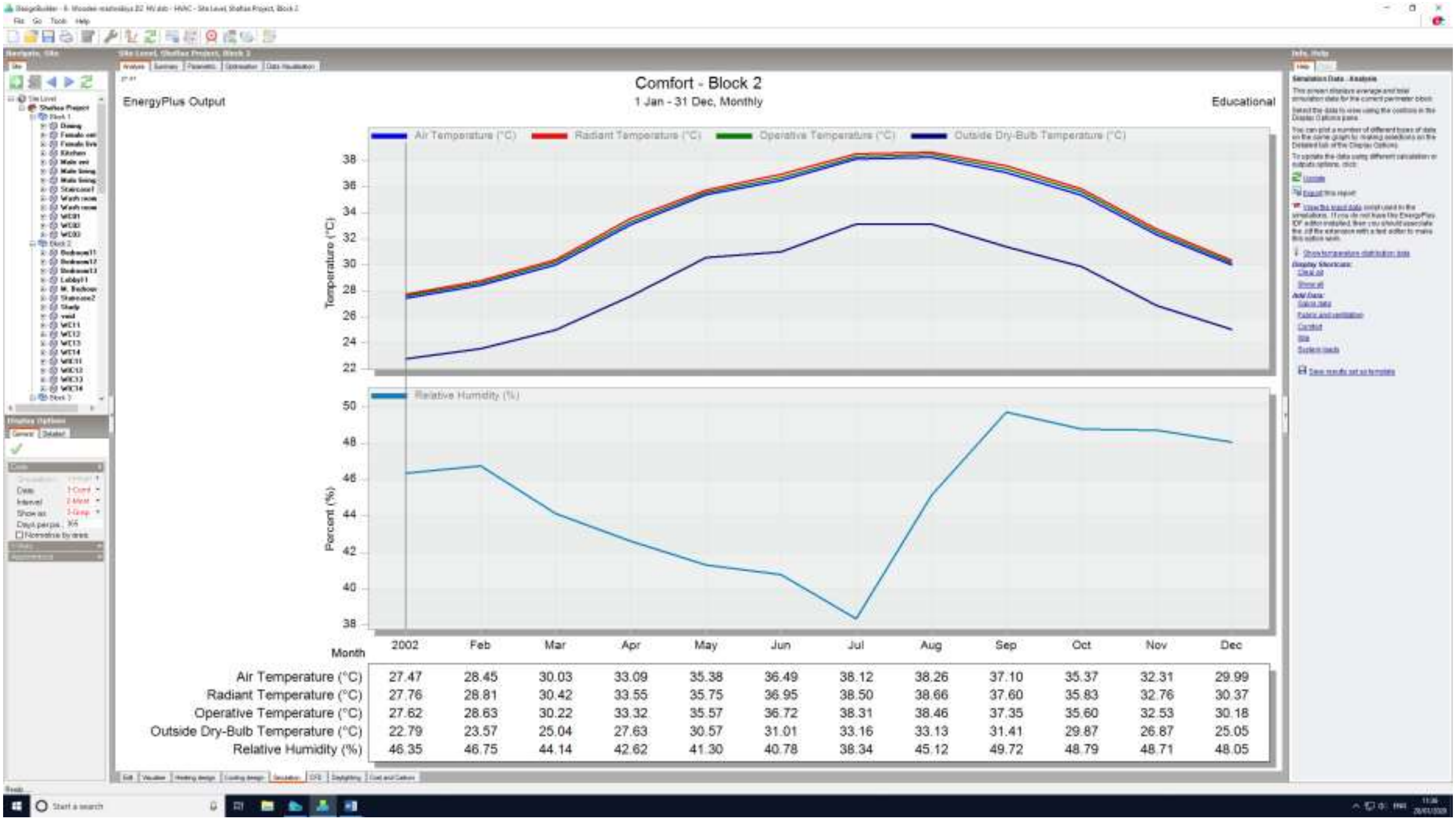




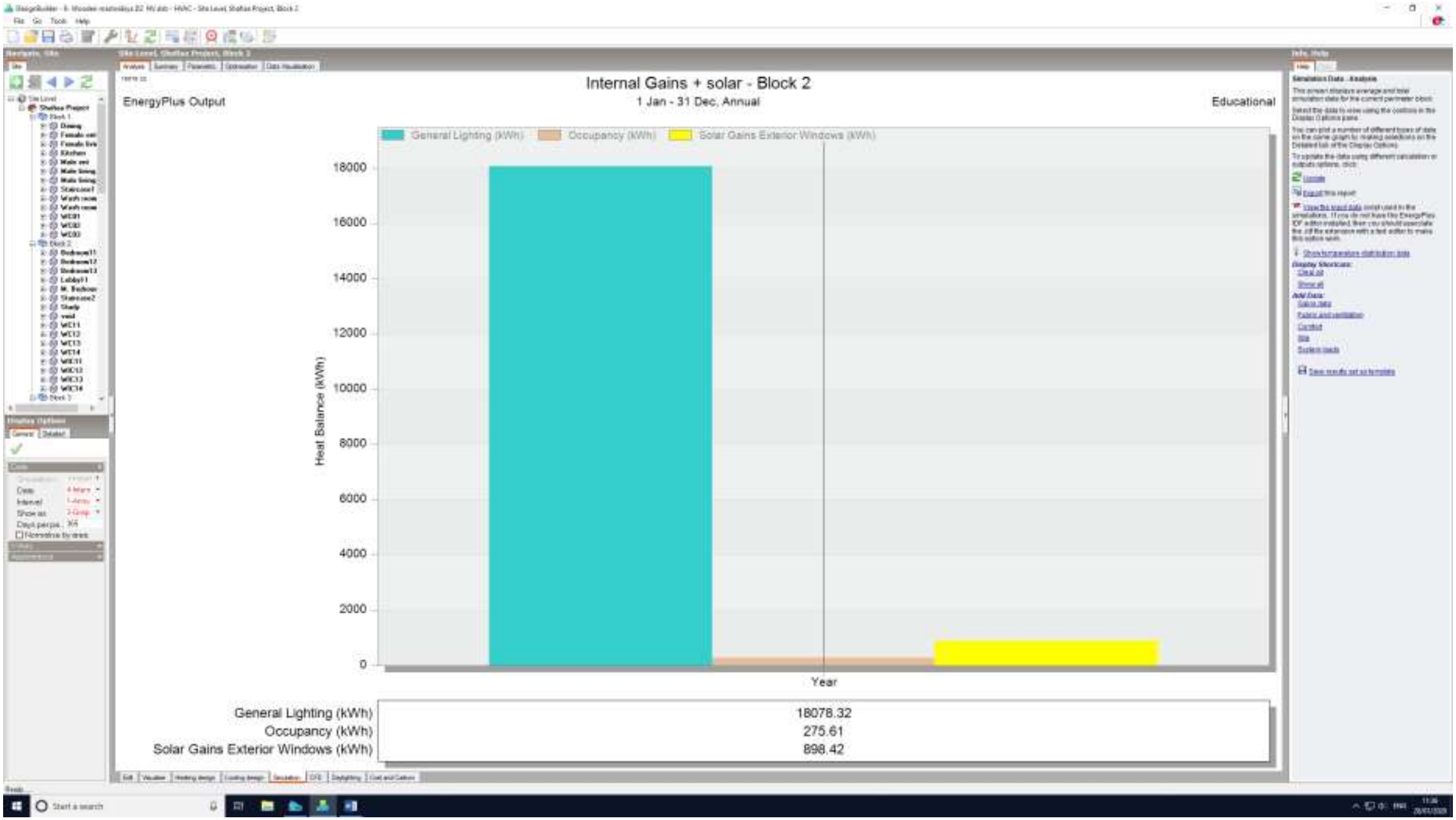
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature (°C)	27.47	28.45	30.03	33.09	35.38	36.49	38.12	38.26	37.10	35.37	32.31	29.99
Radiant Temperature (°C)	27.76	28.81	30.42	33.55	35.75	36.95	38.50	38.66	37.60	35.83	32.76	30.37
Operative Temperature (°C)	27.62	28.63	30.22	33.32	35.57	36.72	38.31	38.46	37.35	35.60	32.53	30.18
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-256.54	-241.82	-273.17	-286.45	-260.16	-284.69	-265.02	-272.40	-294.09	-295.39	-285.09	-269.07
External Vent. (kWh)	-719.56	-710.18	-827.82	-864.47	-811.38	-850.72	-806.83	-799.97	-859.18	-889.49	-840.35	-811.71
General Lighting (kWh)	1535.57	1386.73	1533.78	1488.34	1533.78	1484.76	1537.36	1533.78	1486.55	1535.57	1484.76	1537.36
Occupancy (kWh)	51.83	42.96	40.05	23.80	13.86	8.96	3.67	2.71	6.48	13.32	27.55	40.42
Solar Gains Exterior Windows (kWh)	73.30	68.84	75.84	72.32	77.76	79.85	77.84	71.45	73.44	75.89	75.93	75.95
Mech Vent + Nat Vent + Infiltration (ac/h)	1.08	1.11	1.13	1.14	1.13	1.14	1.14	1.13	1.14	1.14	1.14	1.14



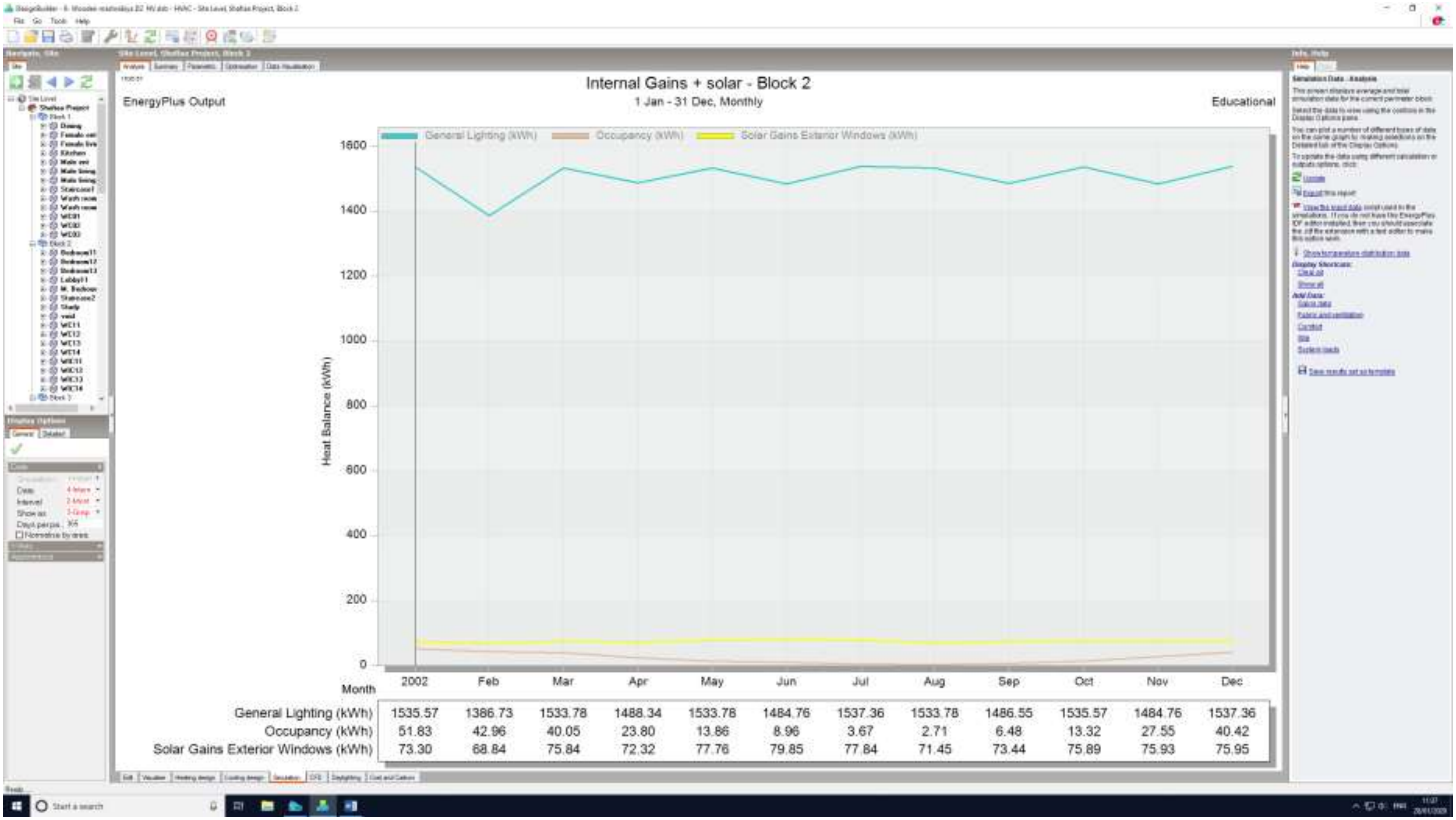
Comfort - Block 2
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Year
Air Temperature (°C) 33.53
Radiant Temperature (°C) 33.94
Operative Temperature (°C) 33.74
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 45.04



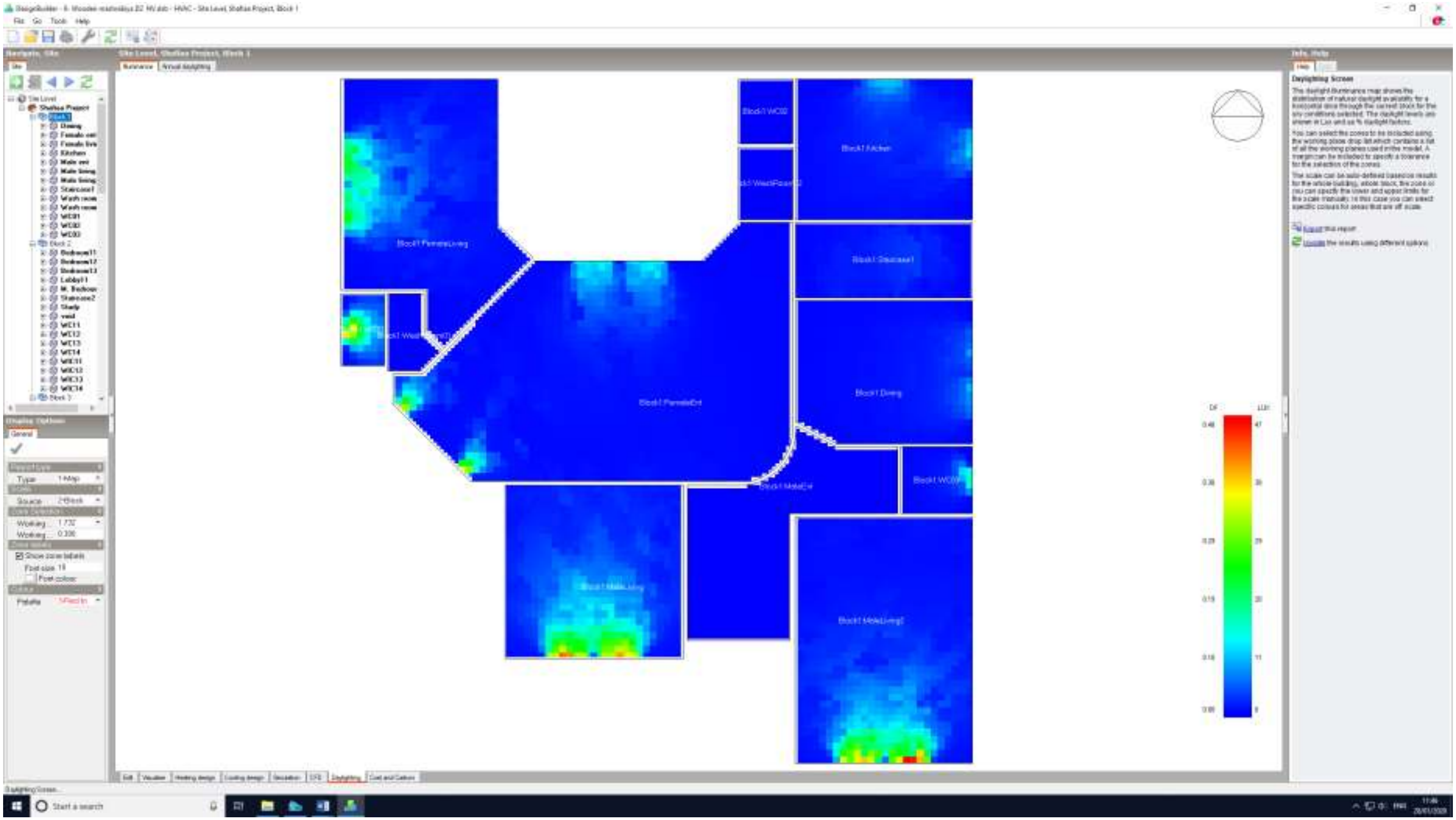
	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature (°C)	27.47	28.45	30.03	33.09	35.38	36.49	38.12	38.26	37.10	35.37	32.31	29.99
Radiant Temperature (°C)	27.76	28.81	30.42	33.55	35.75	36.95	38.50	38.66	37.60	35.83	32.76	30.37
Operative Temperature (°C)	27.62	28.63	30.22	33.32	35.57	36.72	38.31	38.46	37.35	35.60	32.53	30.18
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
Relative Humidity (%)	46.35	46.75	44.14	42.62	41.30	40.78	38.34	45.12	49.72	48.79	48.71	48.05

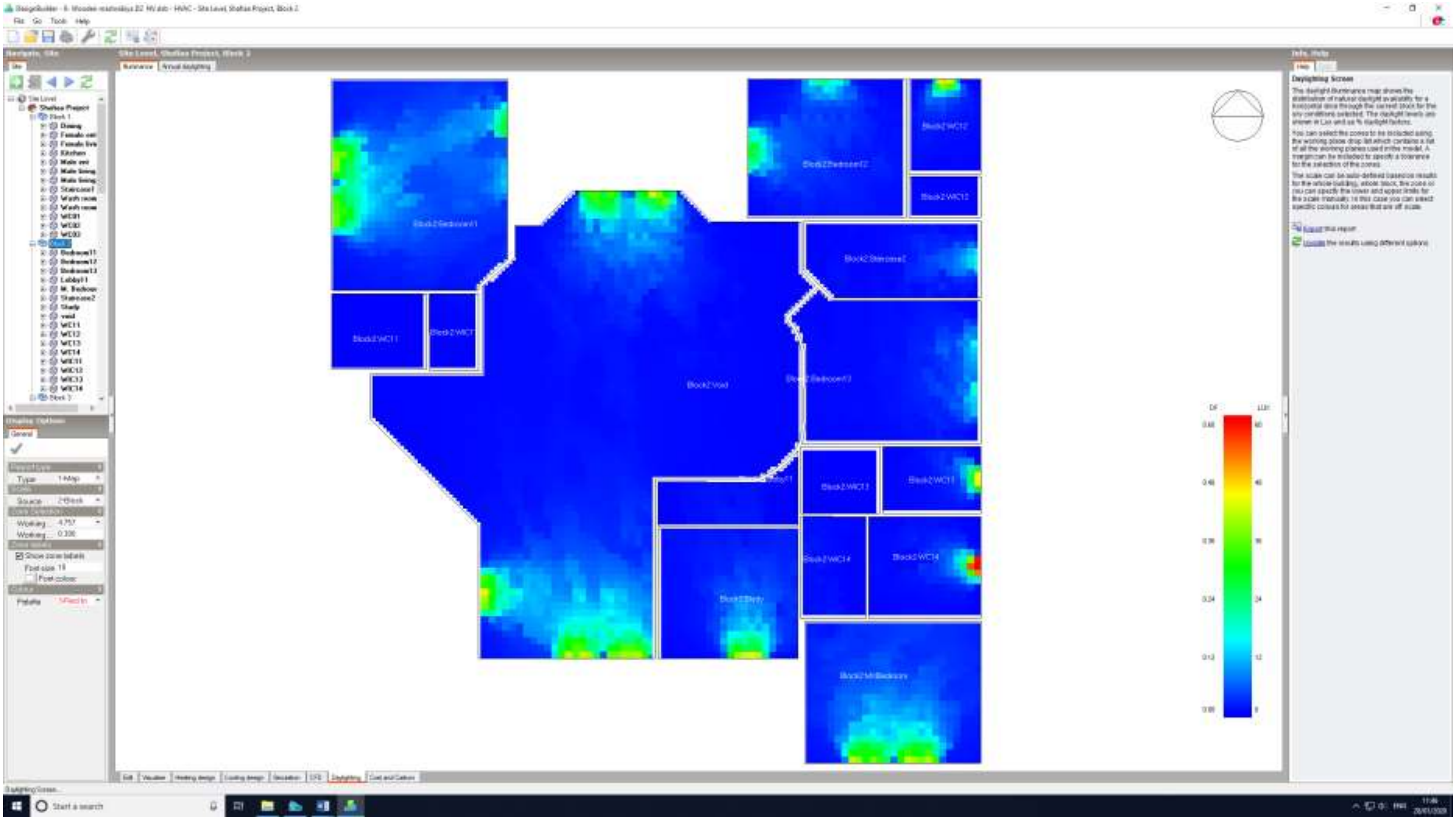


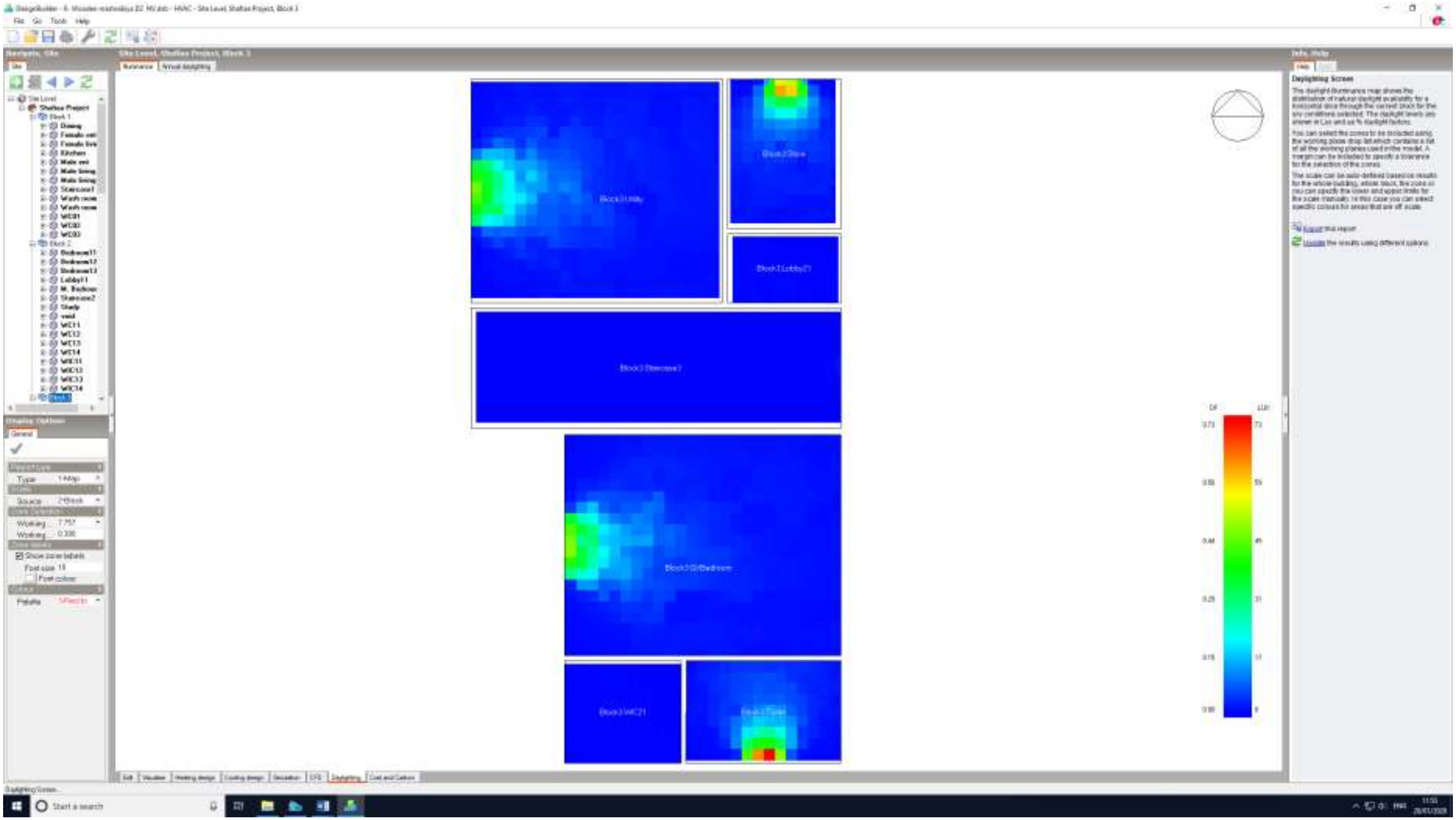
Internal Gains + solar - Block 2
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
General Lighting (kWh)
Occupancy (kWh)
Solar Gains Exterior Windows (kWh)
Heat Balance (kWh)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Year
General Lighting (kWh) 18078.32
Occupancy (kWh) 275.61
Solar Gains Exterior Windows (kWh) 898.42



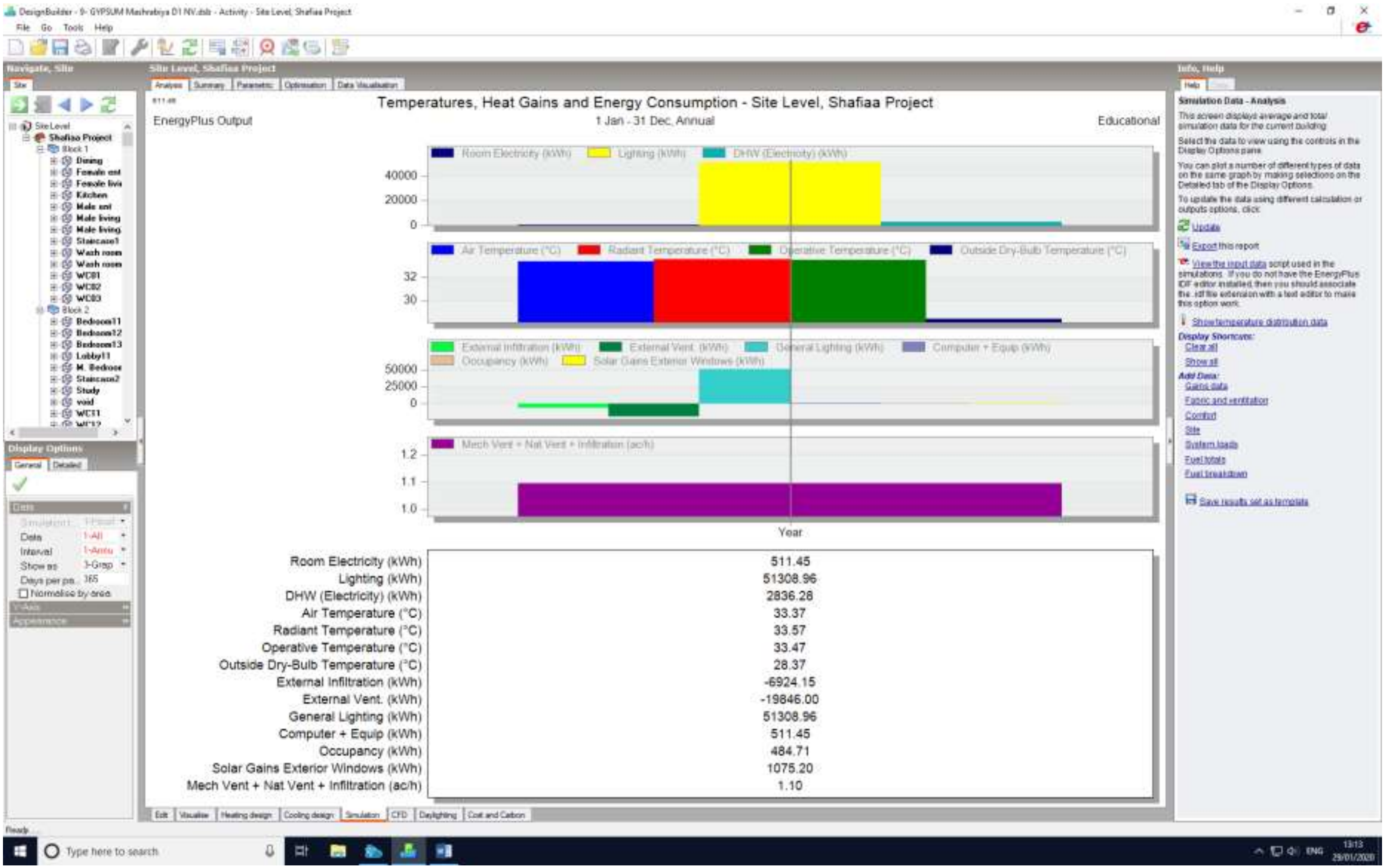
Internal Gains + solar - Block 2
1 Jan - 31 Dec, Monthly
EnergyPlus Output
Educational
General Lighting (kWh)
Occupancy (kWh)
Solar Gains Exterior Windows (kWh)
Heat Balance (kWh)
1600
1400
1200
1000
800
600
400
200
0
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
General Lighting (kWh) 1535.57 1386.73 1533.78 1488.34 1533.78 1484.76 1537.36 1533.78 1486.55 1535.57 1484.76 1537.36
Occupancy (kWh) 51.83 42.96 40.05 23.80 13.86 8.96 3.67 2.71 6.48 13.32 27.55 40.42
Solar Gains Exterior Windows (kWh) 73.30 68.84 75.84 72.32 77.76 79.85 77.84 71.45 73.44 75.89 75.93 75.95

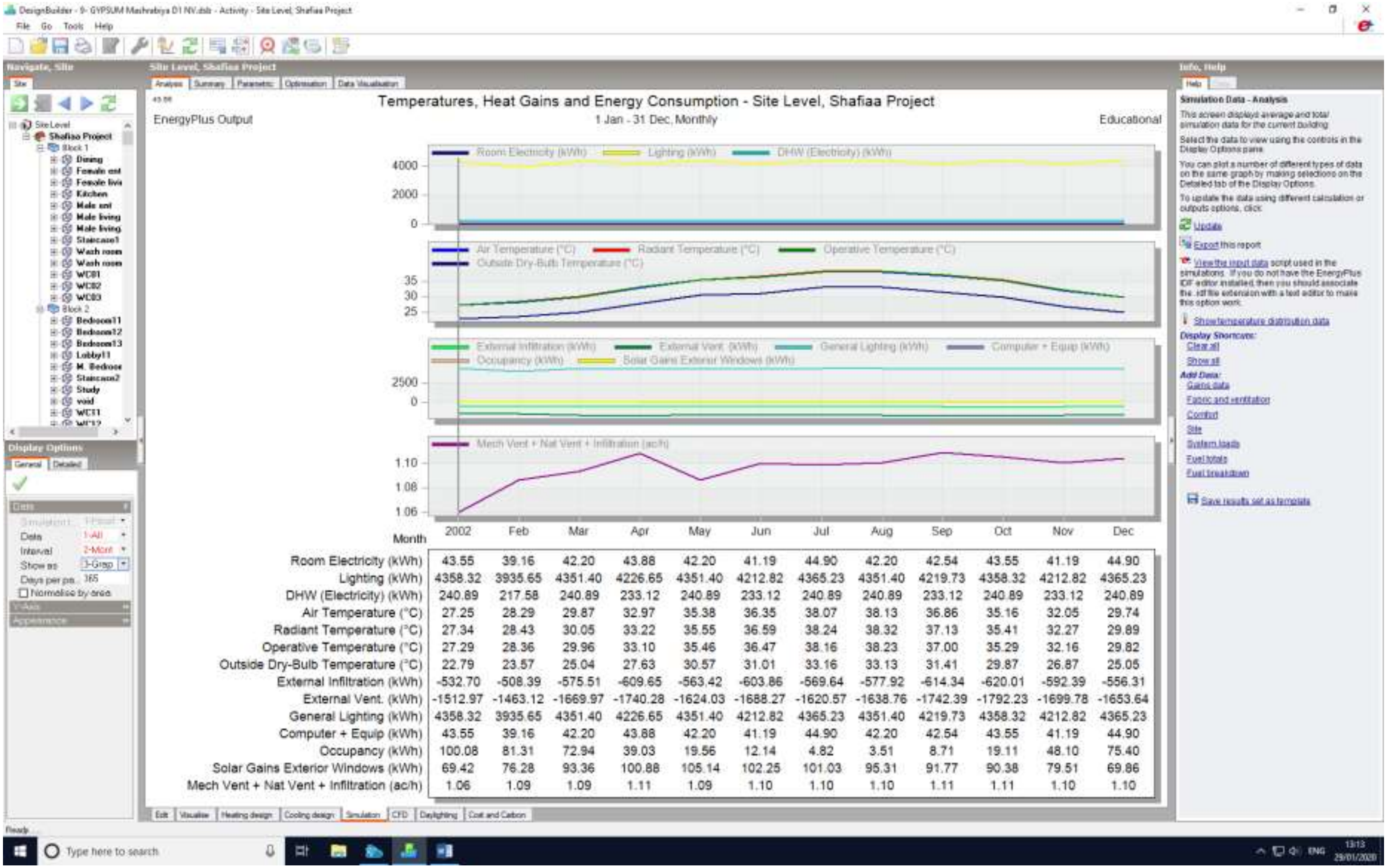




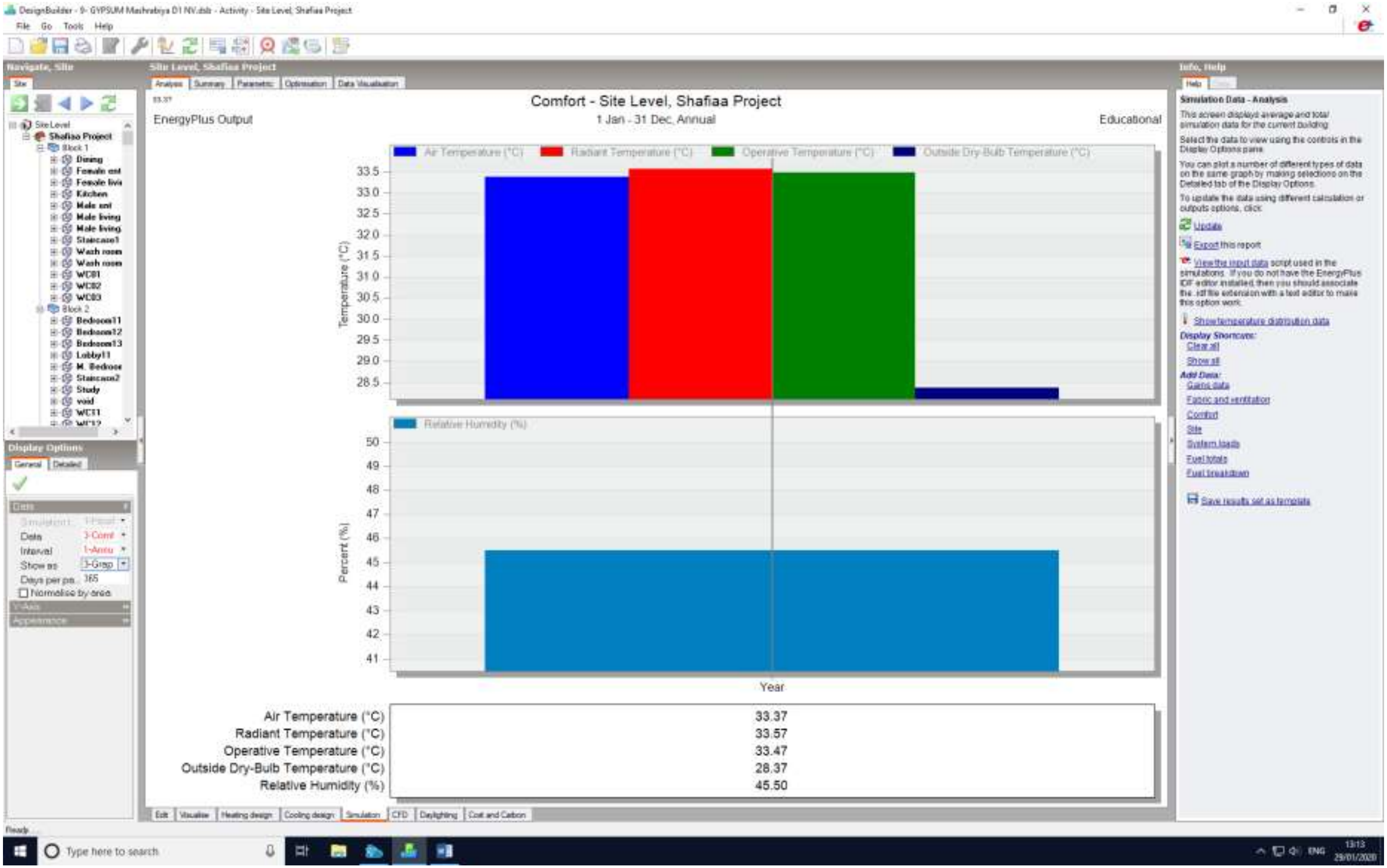


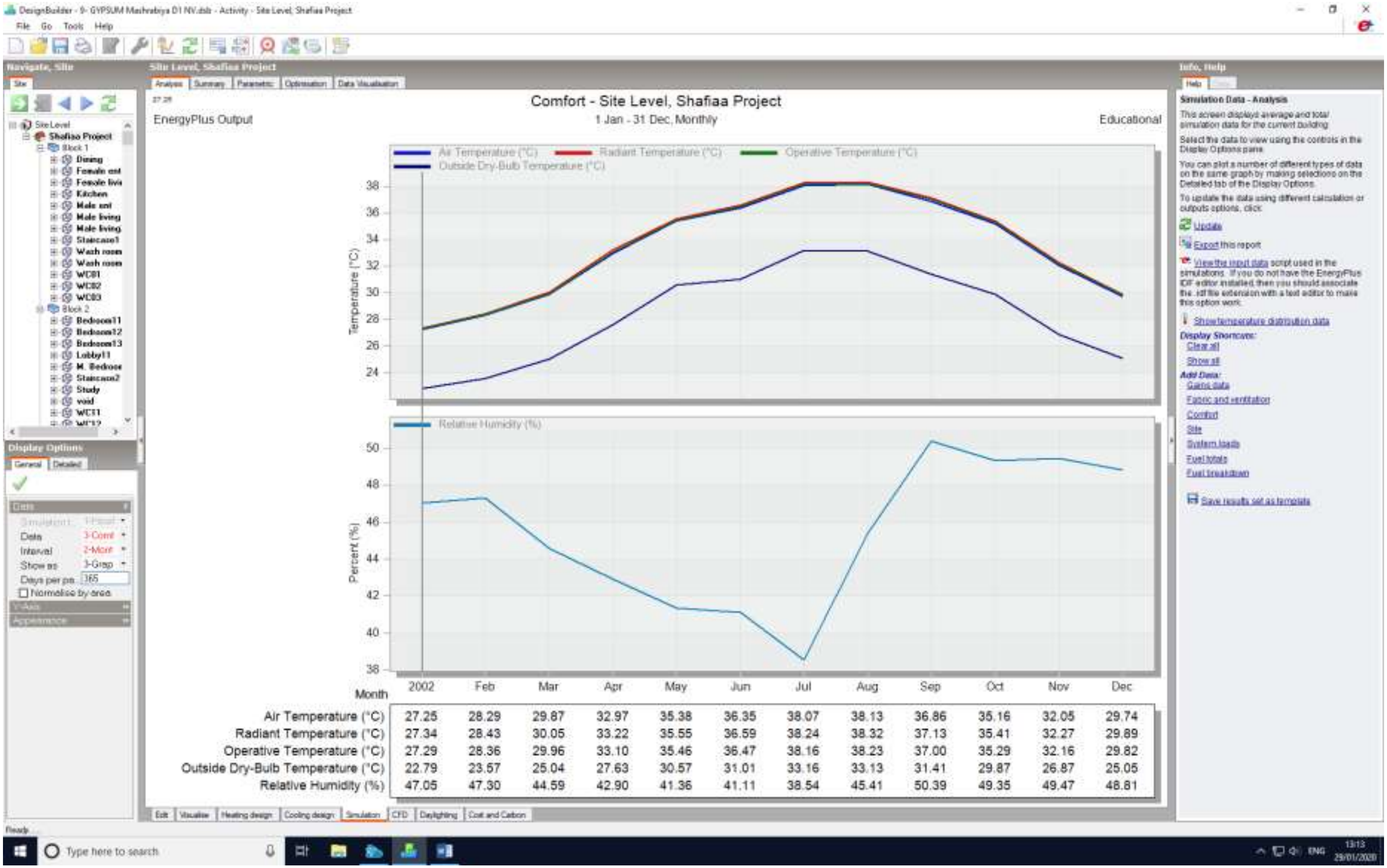
4- Gypsum mashrabiya D1 without AC



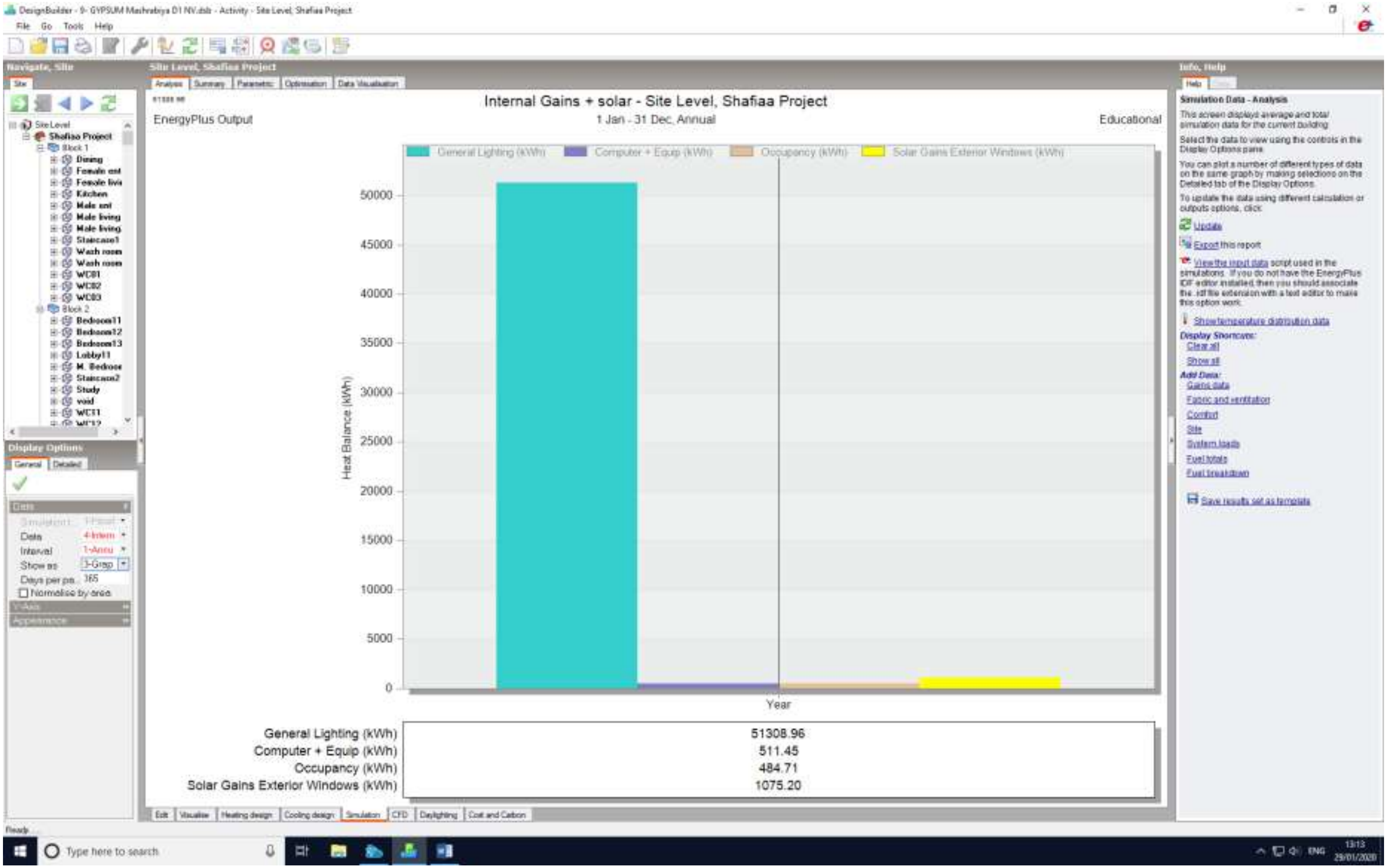


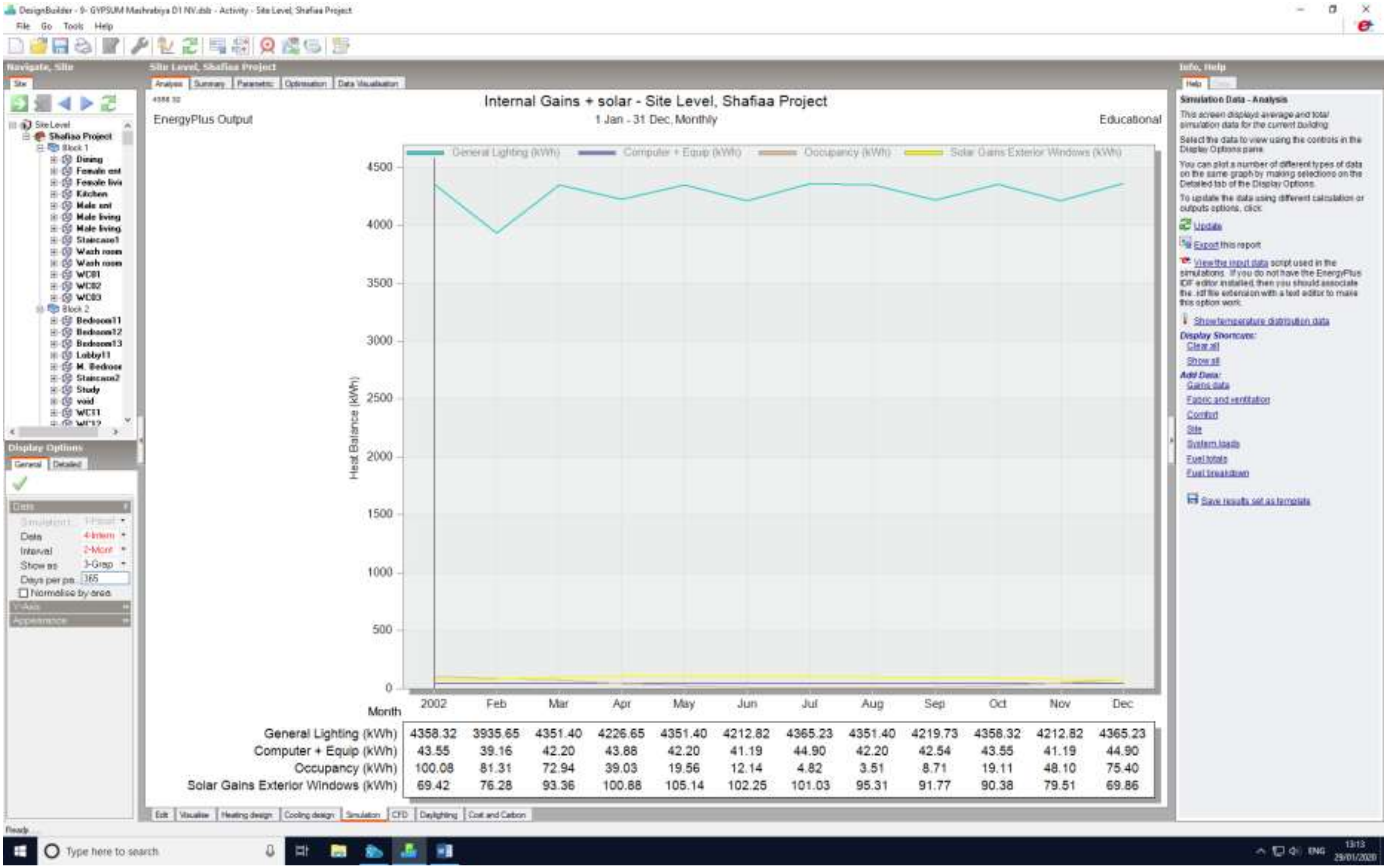
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Room Electricity (kWh)	43.55	39.16	42.20	43.88	42.20	41.19	44.90	42.20	42.54	43.55	41.19	44.90
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
DHW (Electricity) (kWh)	240.89	217.58	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89
Air Temperature (°C)	27.25	28.29	29.87	32.97	35.38	36.35	38.07	38.13	36.86	35.16	32.05	29.74
Radiant Temperature (°C)	27.34	28.43	30.05	33.22	35.55	36.59	38.24	38.32	37.13	35.41	32.27	29.89
Operative Temperature (°C)	27.29	28.36	29.96	33.10	35.46	36.47	38.16	38.23	37.00	35.29	32.16	29.82
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-532.70	-508.39	-575.51	-609.65	-563.42	-603.86	-569.64	-577.92	-614.34	-620.01	-592.39	-556.31
External Vent. (kWh)	-1512.97	-1463.12	-1669.97	-1740.28	-1624.03	-1688.27	-1620.57	-1638.76	-1742.39	-1792.23	-1699.78	-1653.64
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Computer + Equip (kWh)	43.55	39.16	42.20	43.88	42.20	41.19	44.90	42.20	42.54	43.55	41.19	44.90
Occupancy (kWh)	100.08	81.31	72.94	39.03	19.56	12.14	4.82	3.51	8.71	19.11	48.10	75.40
Solar Gains Exterior Windows (kWh)	69.42	76.28	93.36	100.88	105.14	102.25	101.03	95.31	91.77	90.38	79.51	69.86
Mech Vent + Nat Vent + Infiltration (ac/h)	1.06	1.09	1.09	1.11	1.09	1.10	1.10	1.10	1.11	1.11	1.10	1.10


Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Year
Air Temperature (°C) 33.37
Radiant Temperature (°C) 33.57
Operative Temperature (°C) 33.47
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 45.50

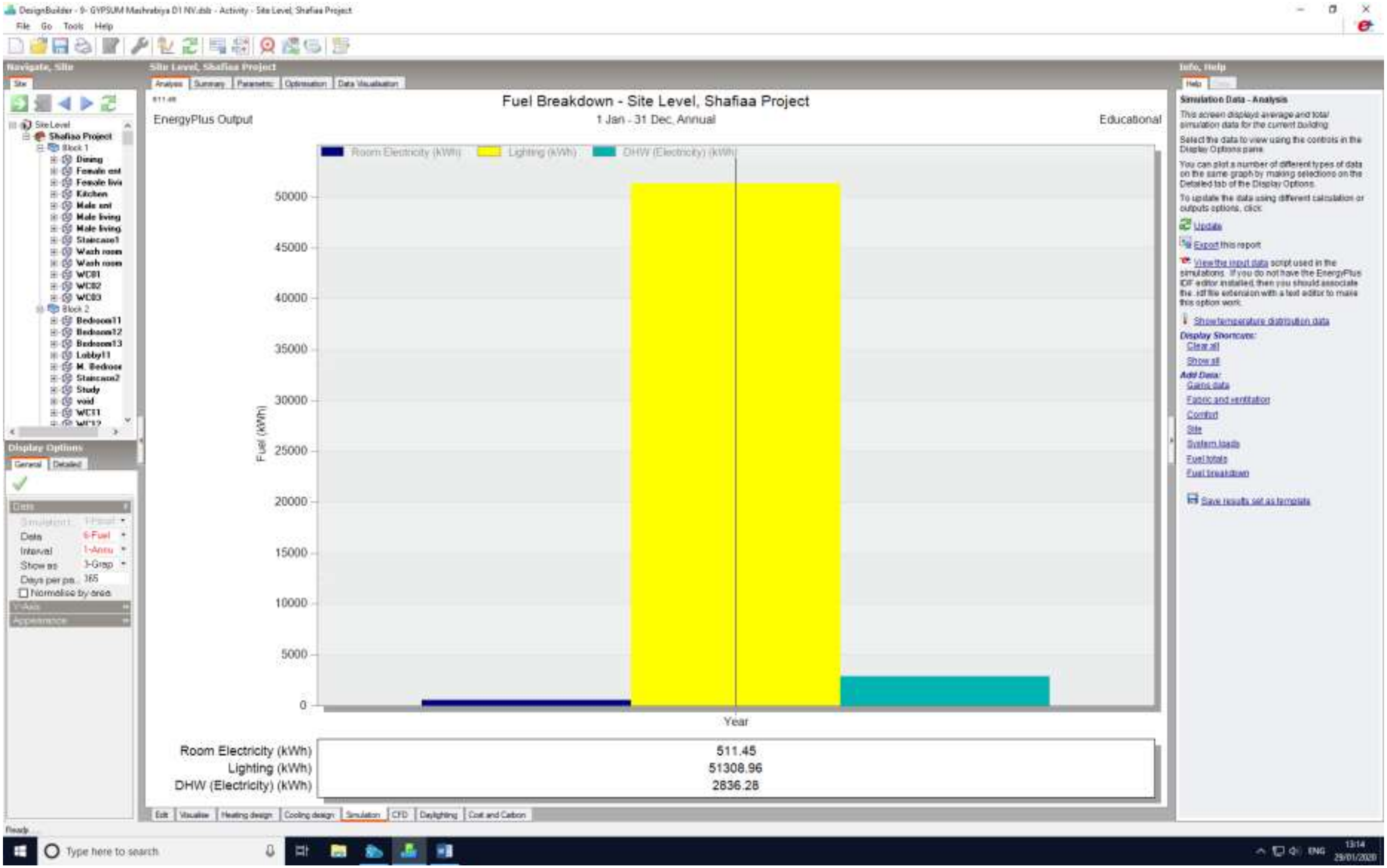


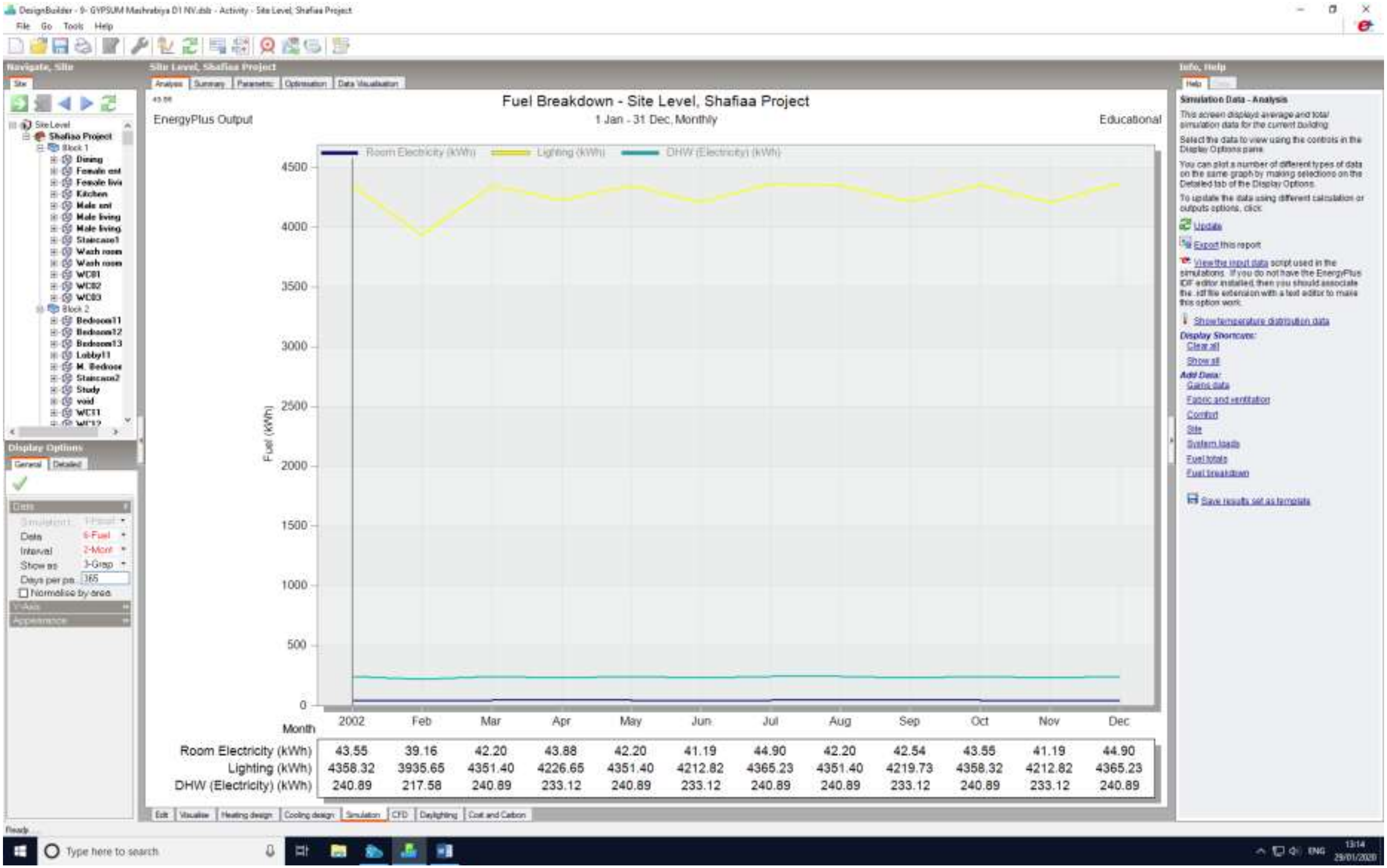
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature (°C)	27.25	28.29	29.87	32.97	35.38	36.35	38.07	38.13	36.86	35.16	32.05	29.74
Radiant Temperature (°C)	27.34	28.43	30.05	33.22	35.55	36.59	38.24	38.32	37.13	35.41	32.27	29.89
Operative Temperature (°C)	27.29	28.36	29.96	33.10	35.46	36.47	38.16	38.23	37.00	35.29	32.16	29.82
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
Relative Humidity (%)	47.05	47.30	44.59	42.90	41.36	41.11	38.54	45.41	50.39	49.35	49.47	48.81

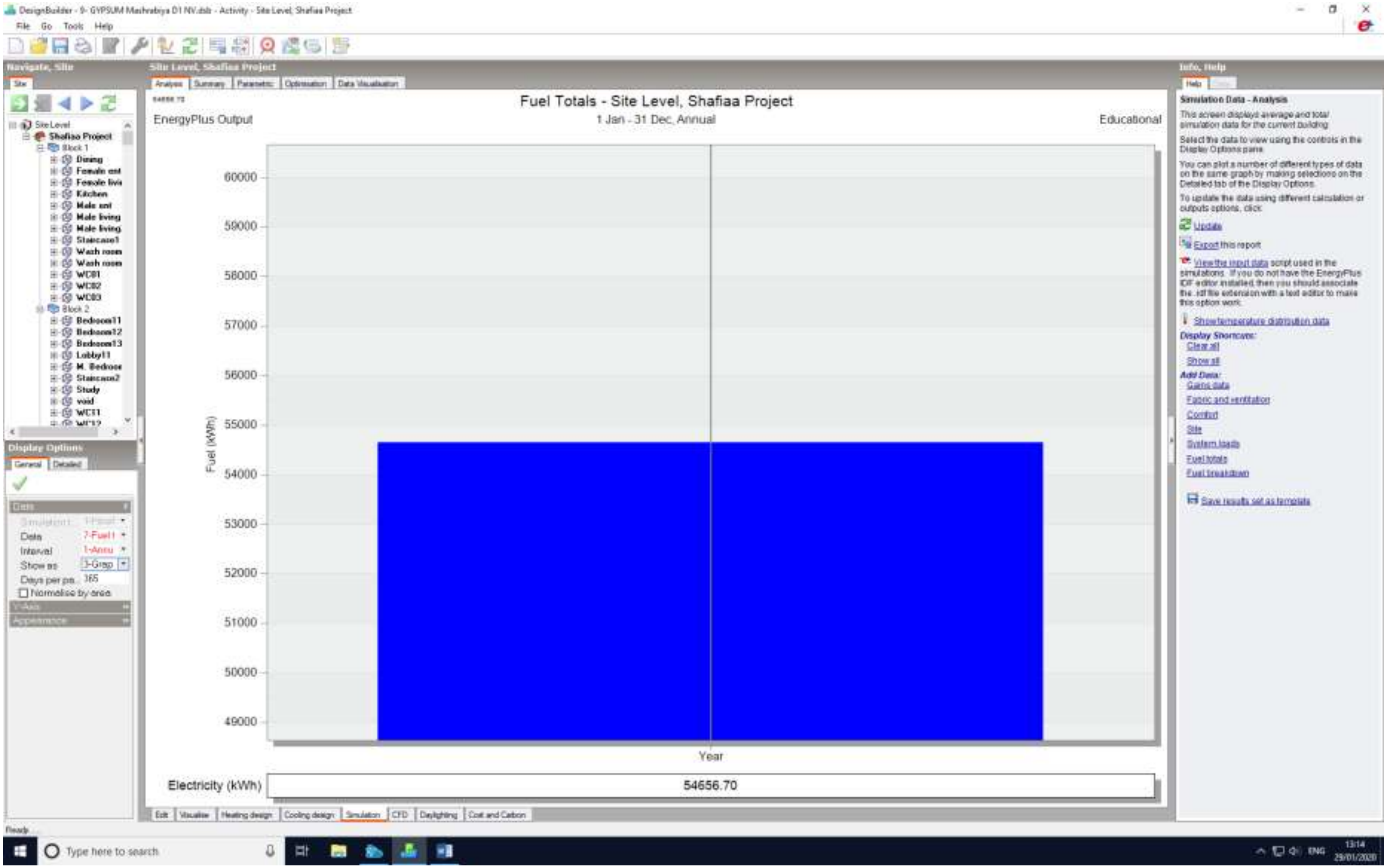

Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
General Lighting (kWh)
Computer + Equip (kWh)
Occupancy (kWh)
Solar Gains Exterior Windows (kWh)
Heat Balance (kWh)
Year
General Lighting (kWh) 51308.96
Computer + Equip (kWh) 511.45
Occupancy (kWh) 484.71
Solar Gains Exterior Windows (kWh) 1075.20



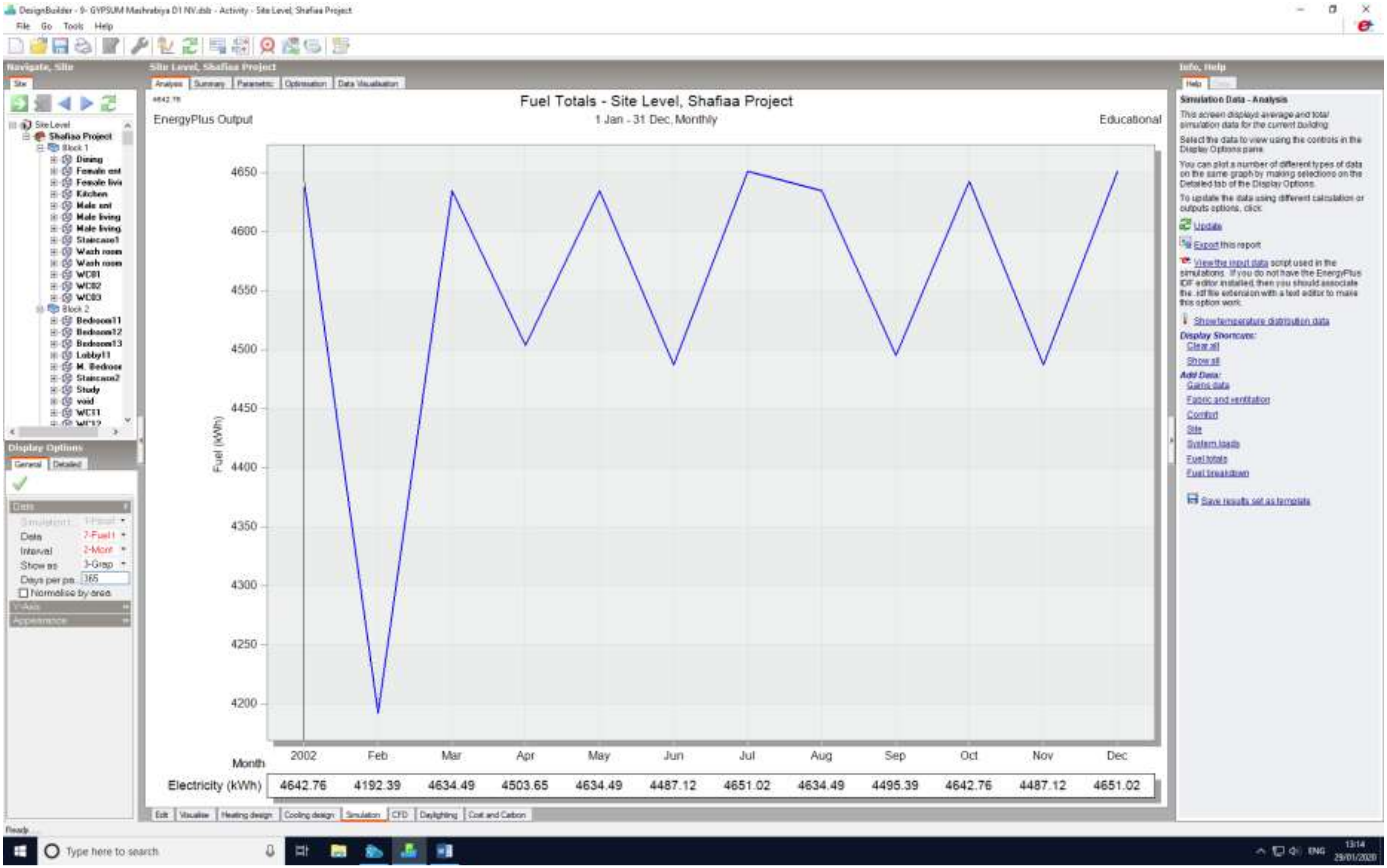
Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
General Lighting (kWh)
Computer + Equip (kWh)
Occupancy (kWh)
Solar Gains Exterior Windows (kWh)
Heat Balance (kWh)
Month
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Computer + Equip (kWh)	43.55	39.16	42.20	43.88	42.20	41.19	44.90	42.20	42.54	43.55	41.19	44.90
Occupancy (kWh)	100.08	81.31	72.94	39.03	19.56	12.14	4.82	3.51	8.71	19.11	48.10	75.40
Solar Gains Exterior Windows (kWh)	69.42	76.28	93.36	100.88	105.14	102.25	101.03	95.31	91.77	90.38	79.51	69.86

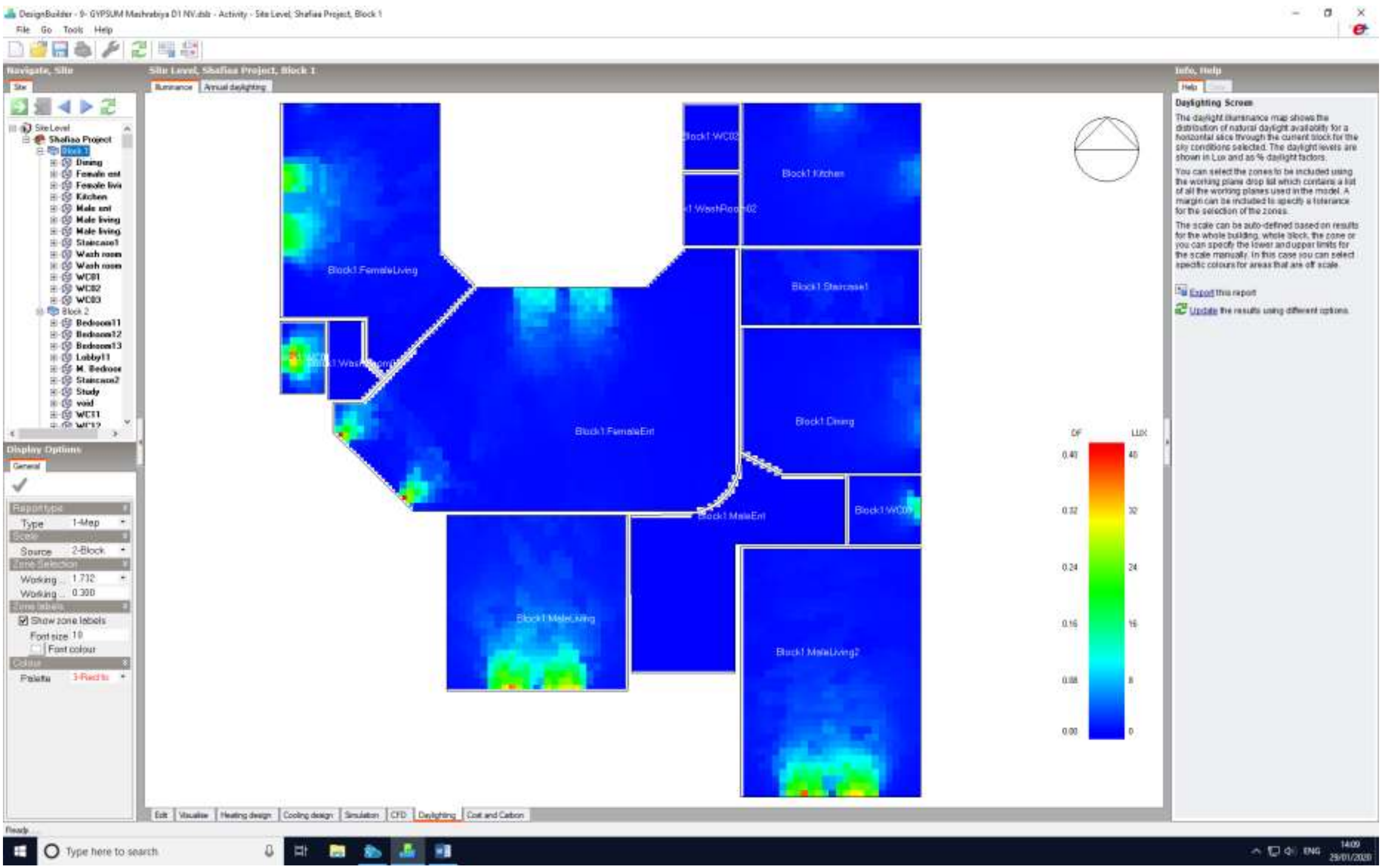

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Room Electricity (kWh)
Lighting (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Year
Room Electricity (kWh) 511.45
Lighting (kWh) 51308.96
DHW (Electricity) (kWh) 2836.28

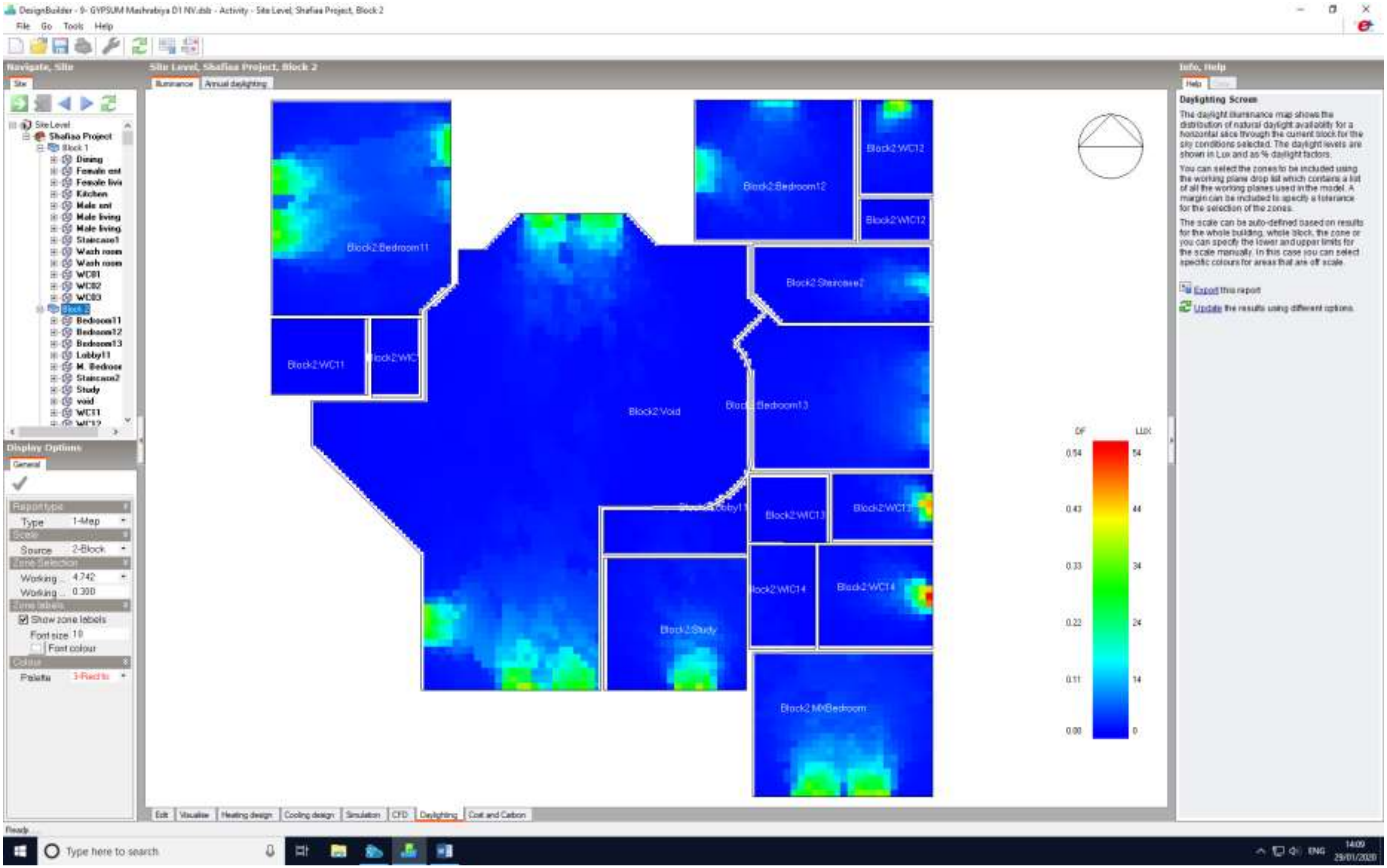

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Room Electricity (kWh)
Lighting (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Room Electricity (kWh) 43.55 39.16 42.20 43.88 42.20 41.19 44.90 42.20 42.54 43.55 41.19 44.90
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89
Simulation Data - Analysis
Display Options
Type here to search



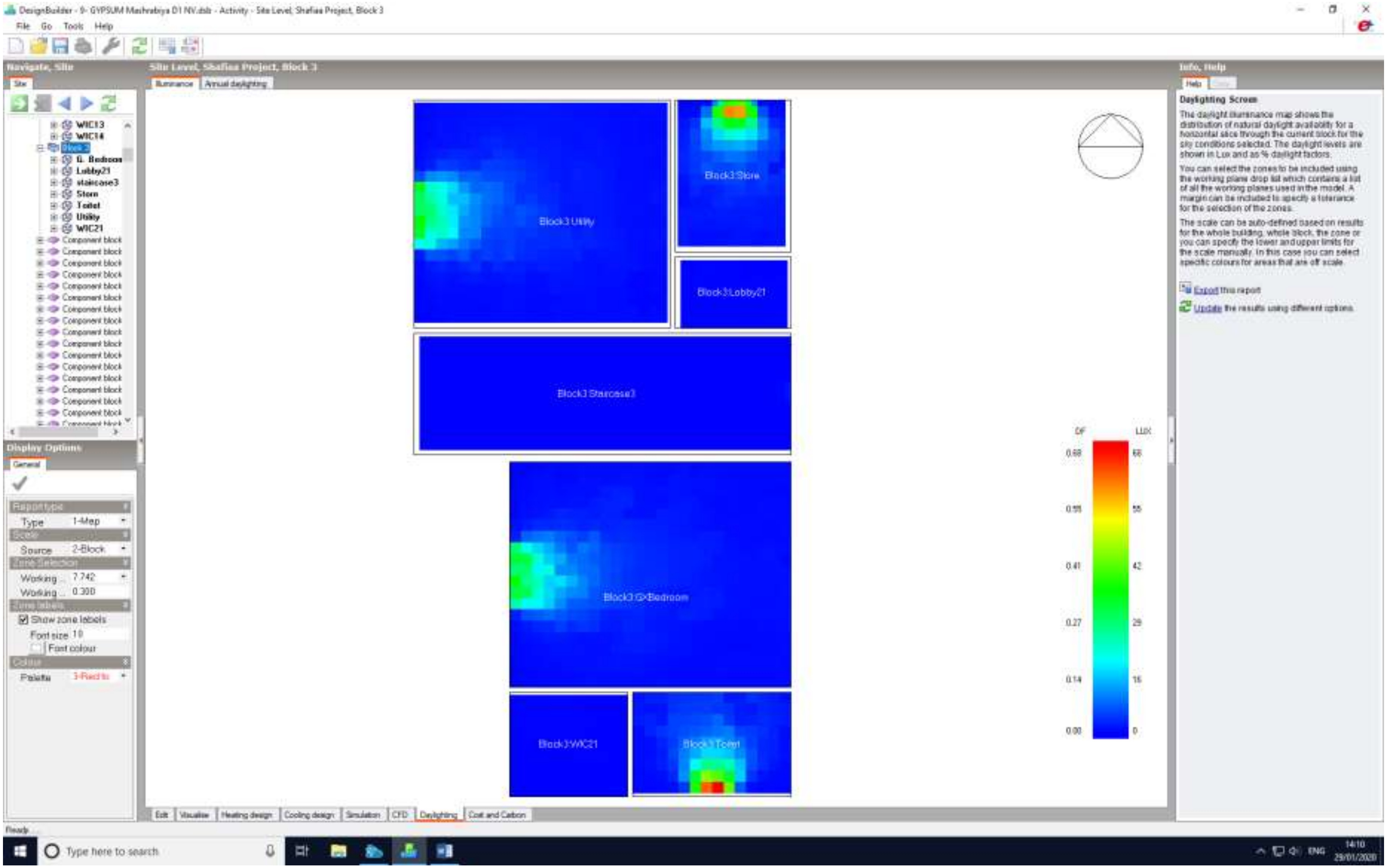
Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Fuel (kWh)
Year
Electricity (kWh)
54656.70


Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Electricity (kWh) 4642.76 4192.39 4634.49 4503.65 4634.49 4487.12 4651.02 4634.49 4495.39 4642.76 4487.12 4651.02

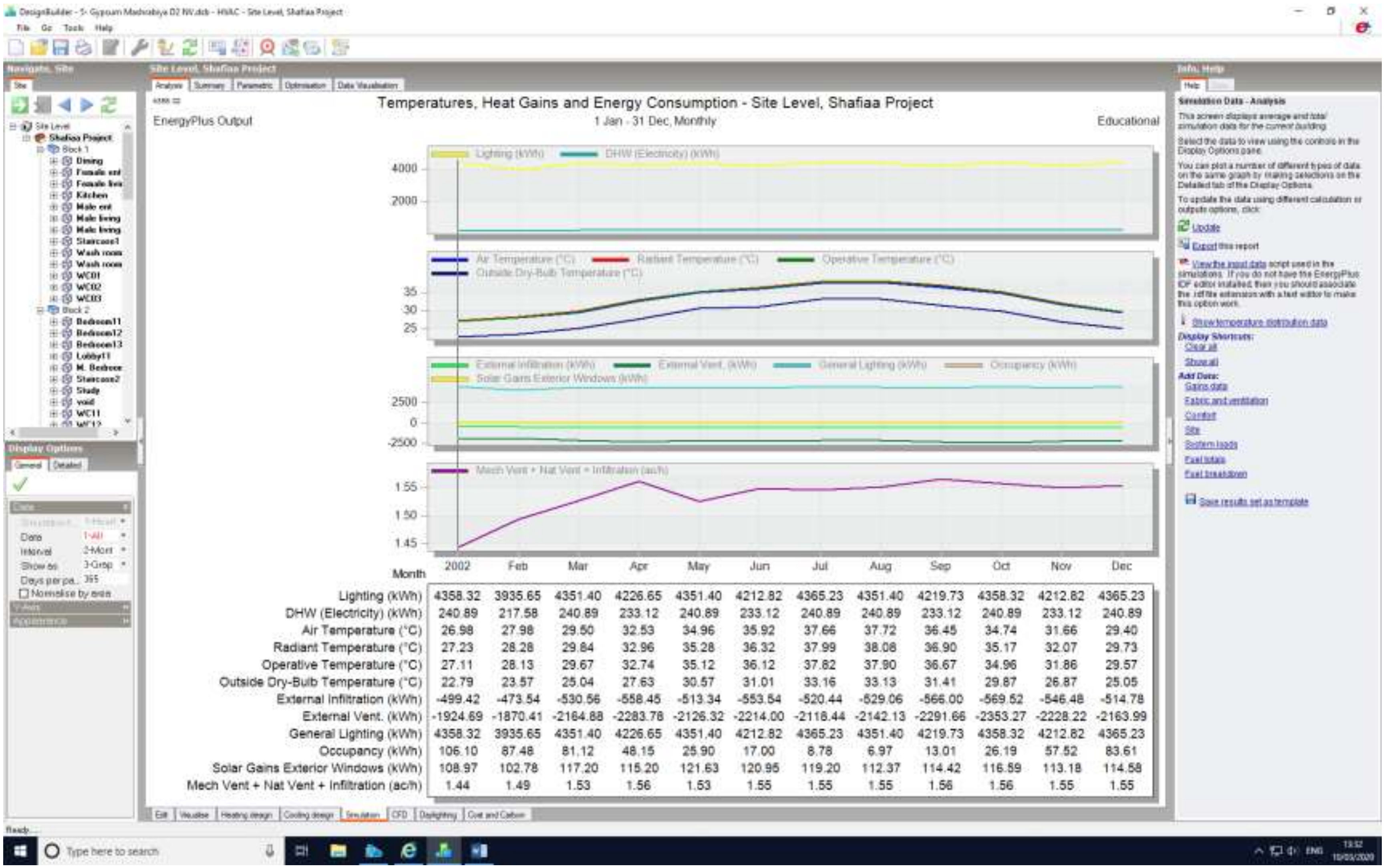

DesignBuilder - 9- GYPSUM Mashrabiya D1 NV.dsb - Activity - Site Level, Shafiaa Project, Block 1
Site Level, Shafiaa Project, Block 1
Daylighting Screen
Block1 FemaleLiving
Block1 Kitchen
Block1 Staircase1
Block1 FemaleEnt
Block1 Dining
Block1 MaleEnt
Block1 MaleLiving
Block1 MaleLiving2
DF
LUX



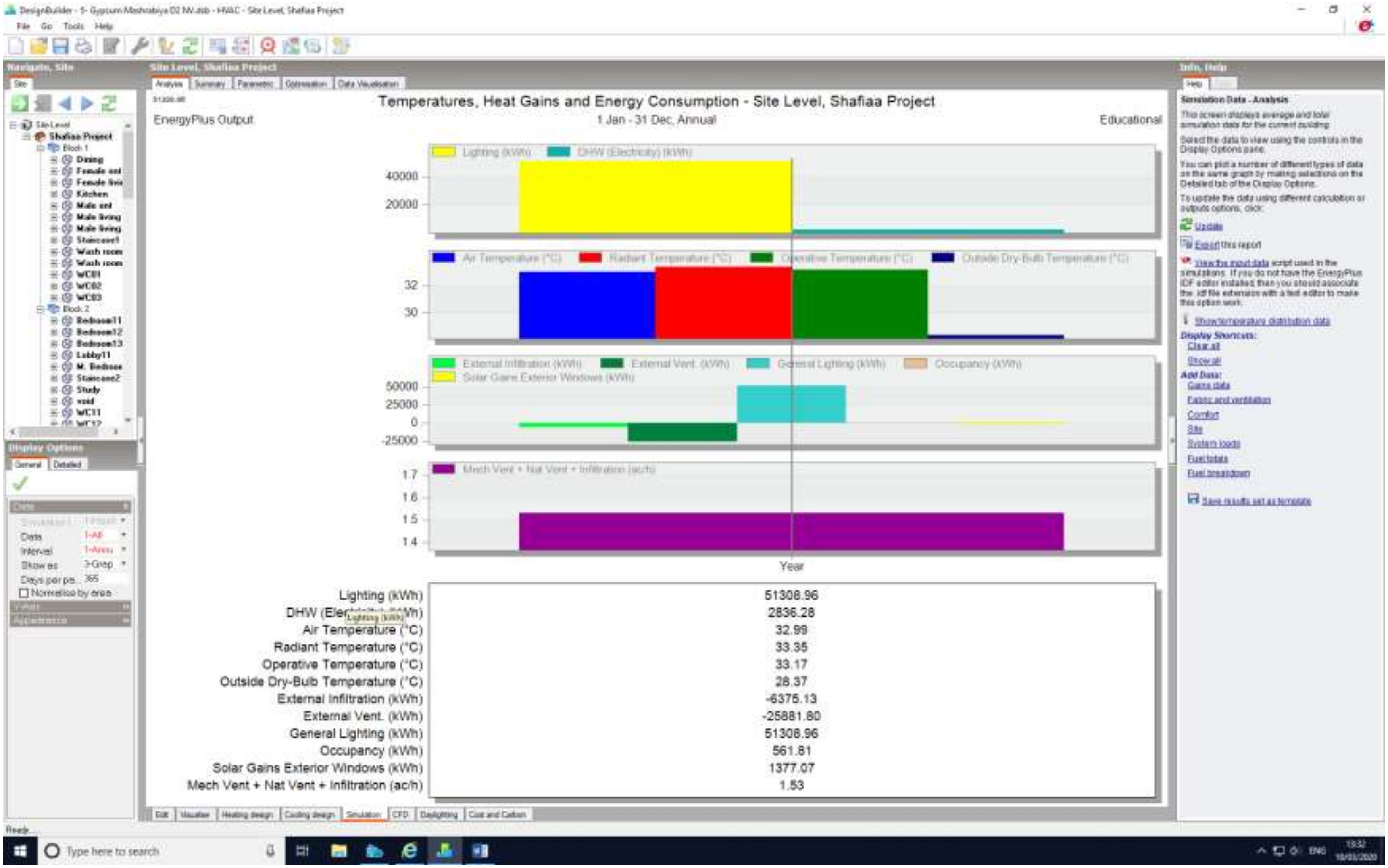
DesignBuilder - 9- GYPSUM Mashrabiya D1 NV.dsb - Activity - Site Level, Shafiaa Project, Block 2
Site Level, Shafiaa Project, Block 2
Block2:Bedroom11
Block2:Bedroom12
Block2:WC12
Block2:WIC12
Block2:Staircase2
Block2:WC11
Block2:Void
Block2:Bedroom13
Block2:WIC13
Block2:WC13
Block2:WIC14
Block2:WC14
Block2:Study
Block2:MBedroom
DF
LUX
Daylighting Screen

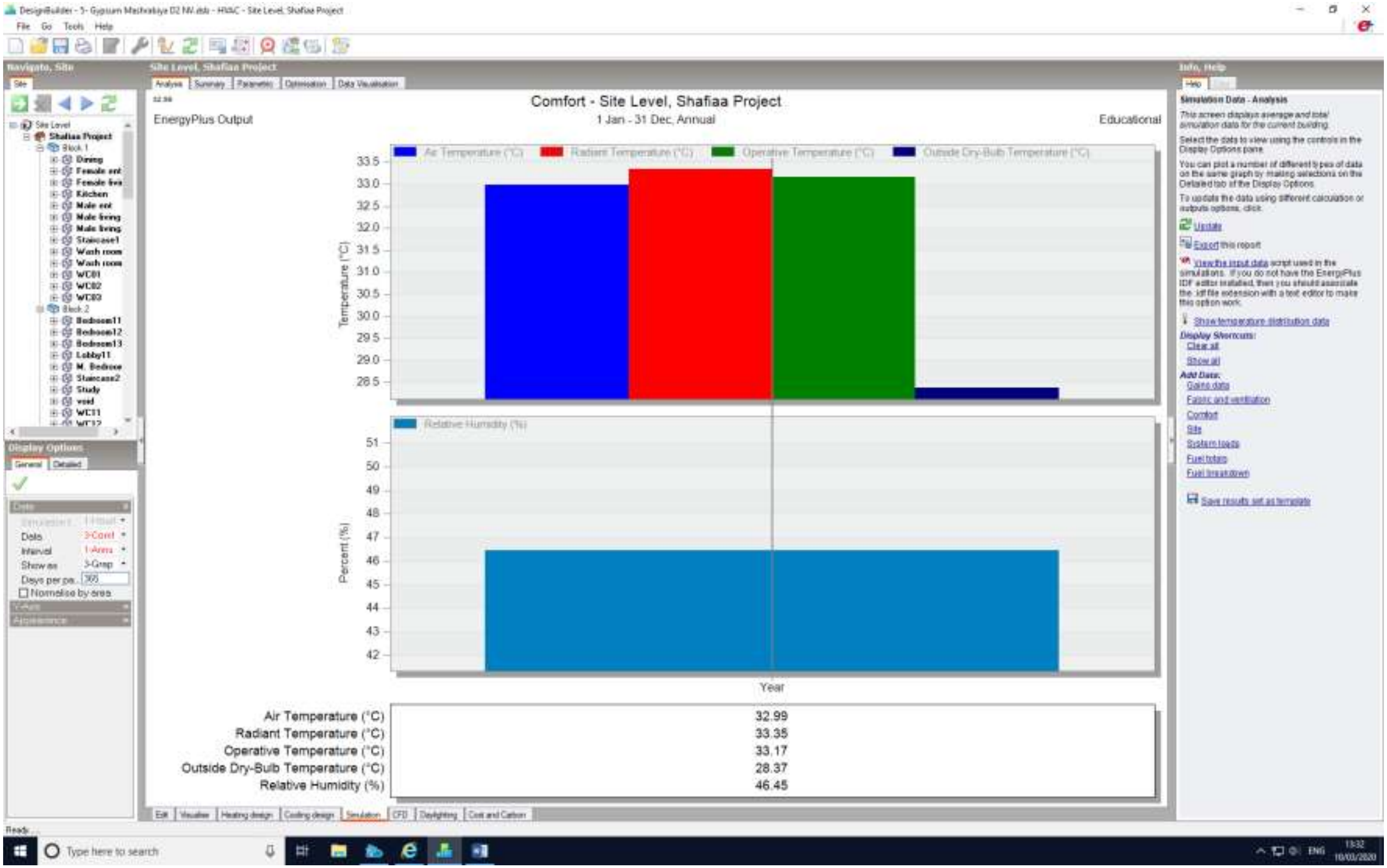

Block3:Utility
Block3:Store
Block3:Lobby21
Block3:Staircase3
Block3:G-Bedroom
Block3:WIC21
Block3:Toilet
DF
LUX
Daylighting Screen
Type here to search

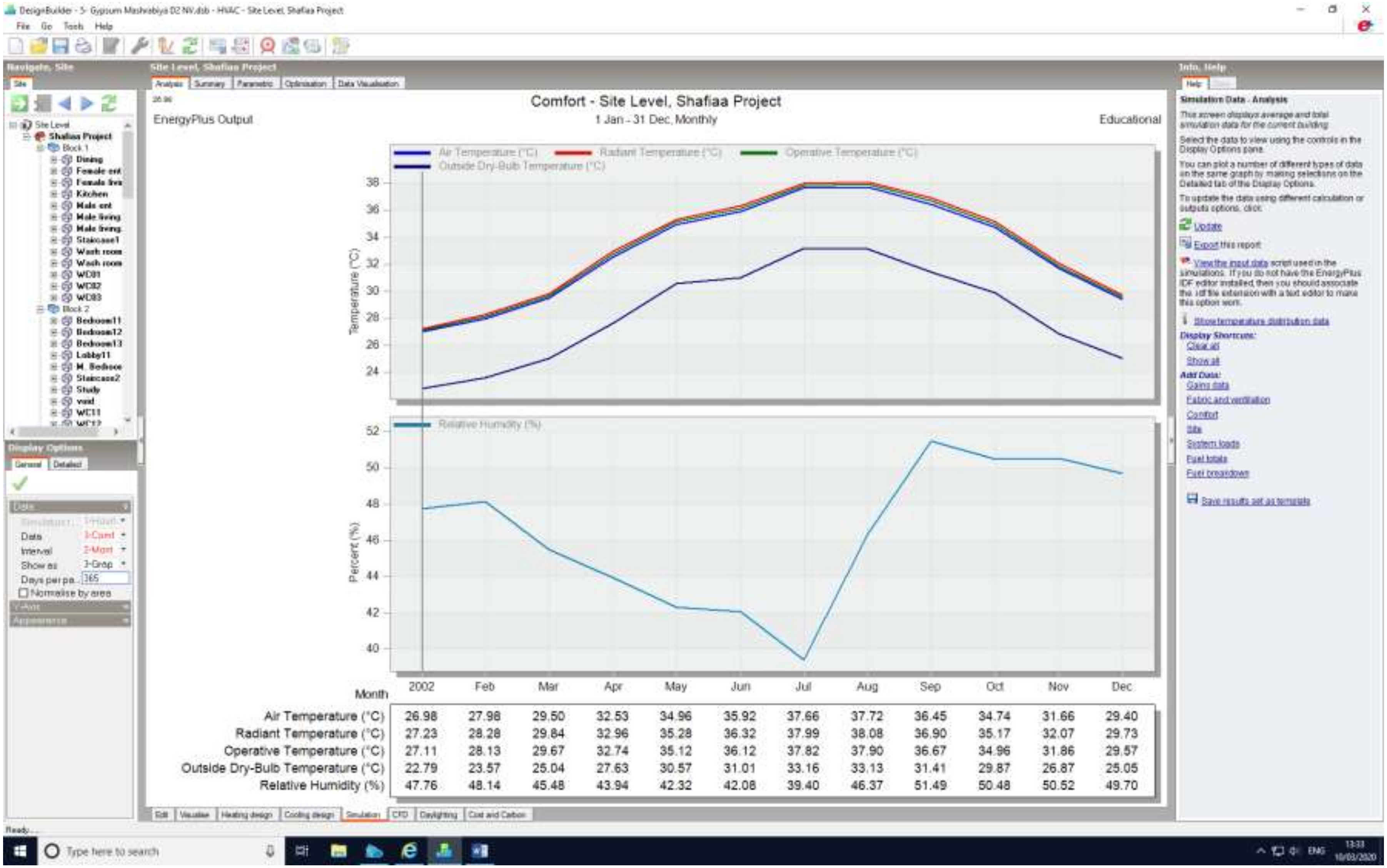
5- Gypsum mashrabiya D2 without AC

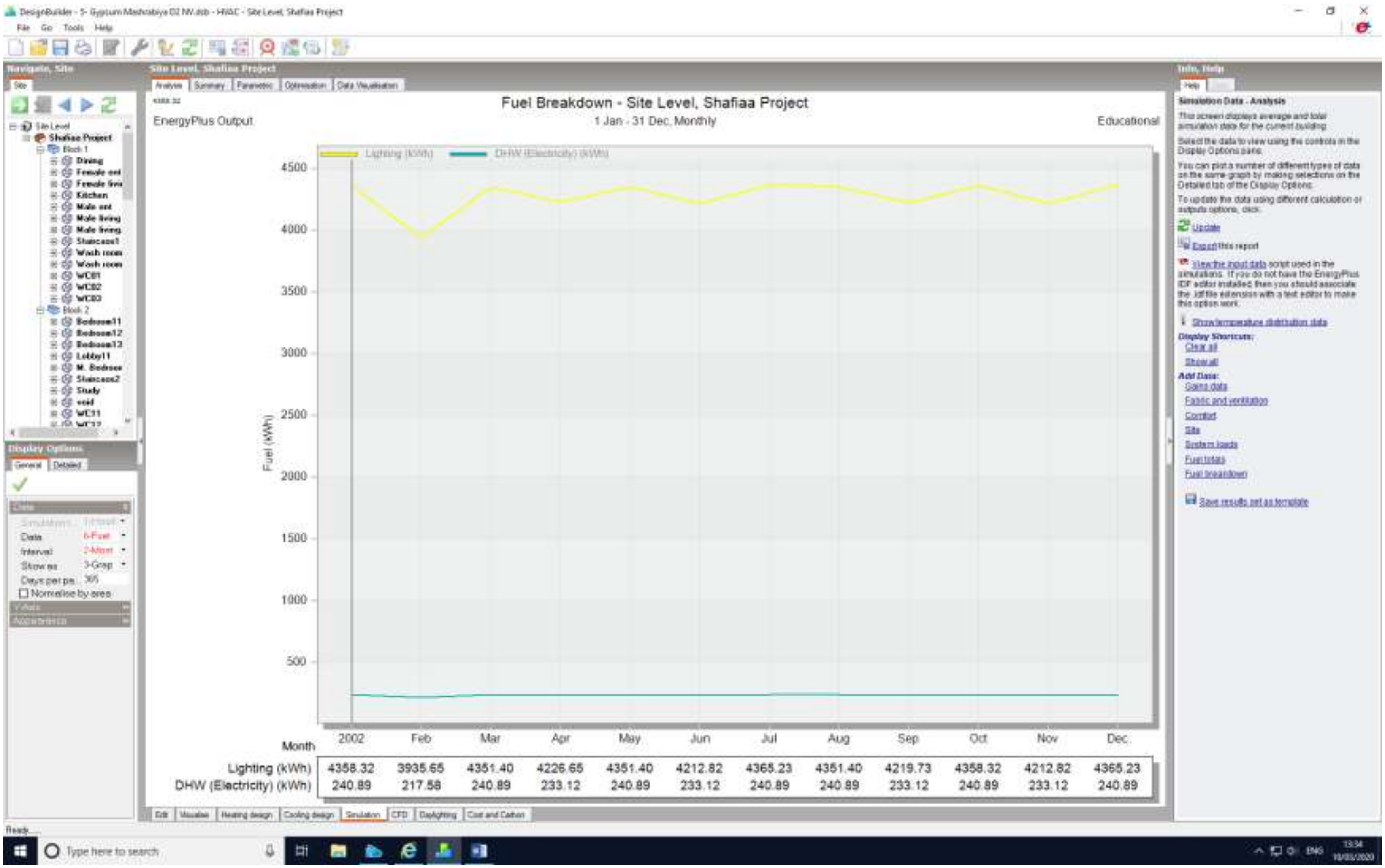


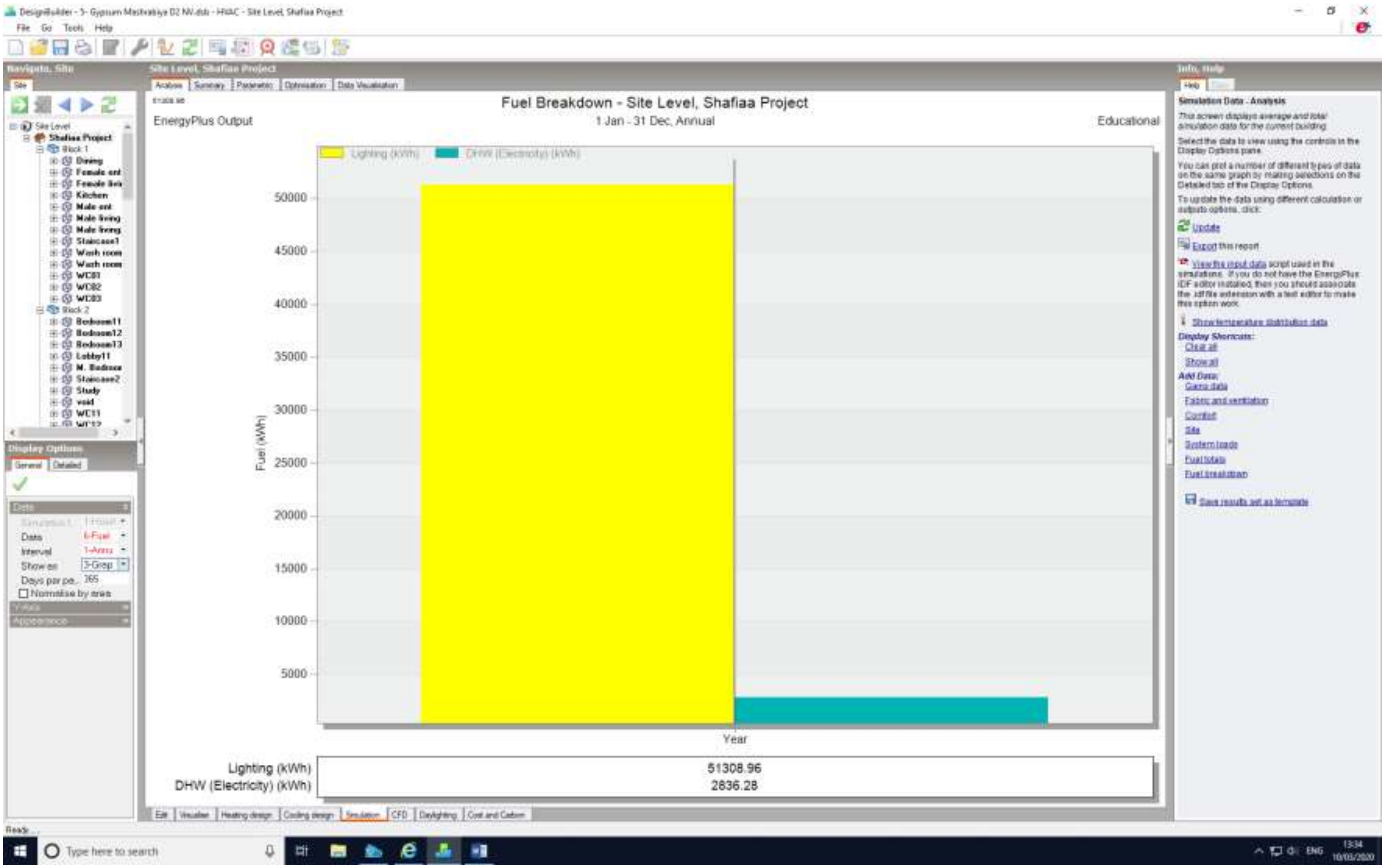
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
DHW (Electricity) (kWh)	240.89	217.58	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89
Air Temperature (°C)	26.98	27.98	29.50	32.53	34.96	35.92	37.66	37.72	36.45	34.74	31.66	29.40
Radiant Temperature (°C)	27.23	28.28	29.84	32.96	35.28	36.32	37.99	38.08	36.90	35.17	32.07	29.73
Operative Temperature (°C)	27.11	28.13	29.67	32.74	35.12	36.12	37.82	37.90	36.67	34.96	31.86	29.57
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-499.42	-473.54	-530.56	-558.45	-513.34	-553.54	-520.44	-529.06	-566.00	-569.52	-546.48	-514.78
External Vent. (kWh)	-1924.69	-1870.41	-2164.88	-2283.78	-2126.32	-2214.00	-2118.44	-2142.13	-2291.66	-2353.27	-2228.22	-2163.99
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Occupancy (kWh)	106.10	87.48	81.12	48.15	25.90	17.00	8.78	6.97	13.01	26.19	57.52	83.61
Solar Gains Exterior Windows (kWh)	108.97	102.78	117.20	115.20	121.63	120.95	119.20	112.37	114.42	116.59	113.18	114.58
Mech Vent + Nat Vent + Infiltration (ac/h)	1.44	1.49	1.53	1.56	1.53	1.55	1.55	1.55	1.56	1.56	1.55	1.55


Temperatures, Heat Gains and Energy Consumption - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
40000
20000
32
30
50000
25000
0
-25000
1.7
1.6
1.5
1.4
Year
Lighting (kWh) 51308.96
DHW (Electricity) (kWh) 2836.28
Air Temperature (°C) 32.99
Radiant Temperature (°C) 33.35
Operative Temperature (°C) 33.17
Outside Dry-Bulb Temperature (°C) 28.37
External Infiltration (kWh) -6375.13
External Vent. (kWh) -25881.80
General Lighting (kWh) 51308.96
Occupancy (kWh) 561.81
Solar Gains Exterior Windows (kWh) 1377.07
Mech Vent + Nat Vent + Infiltration (ac/h) 1.53

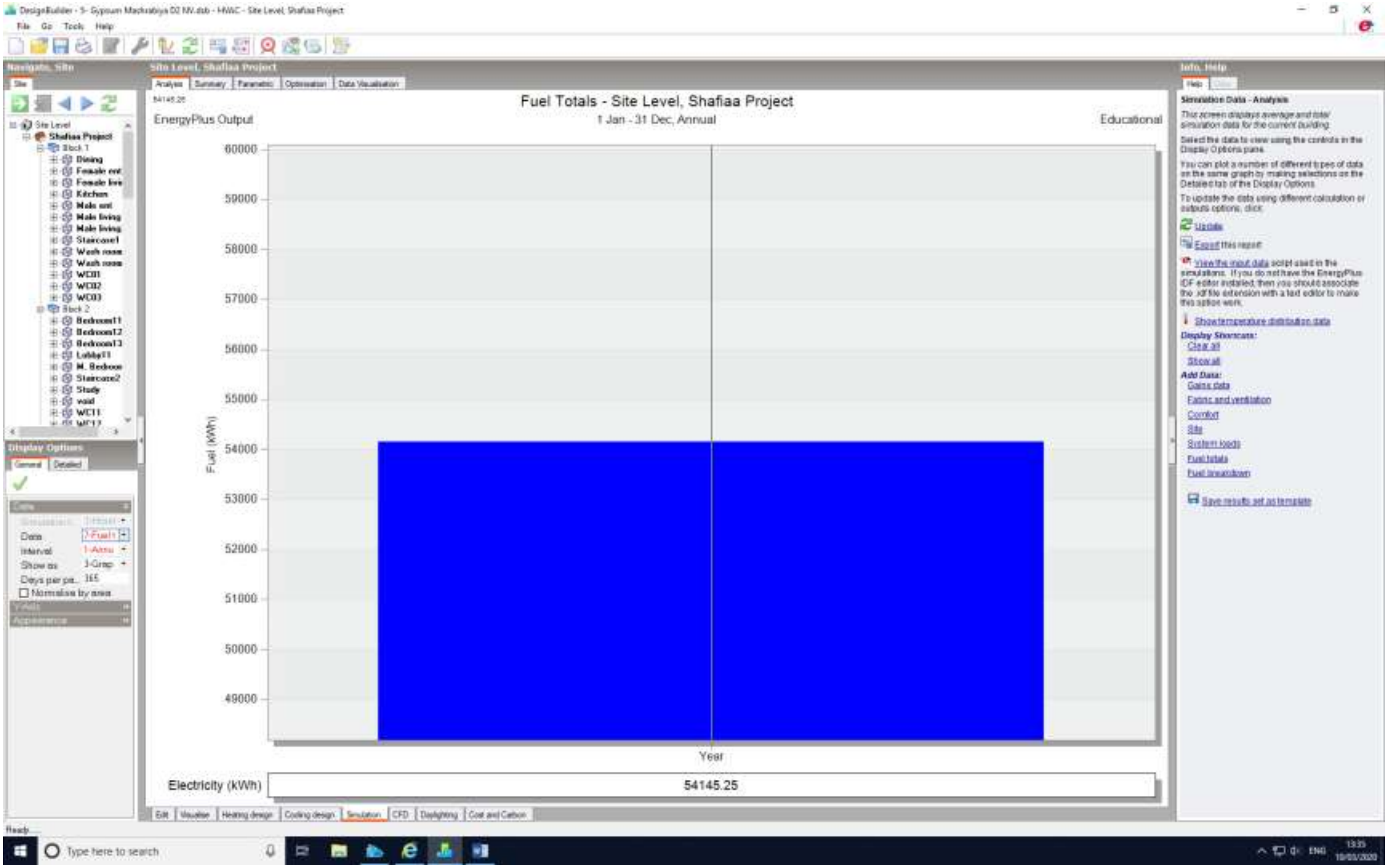

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Year
Air Temperature (°C) 32.99
Radiant Temperature (°C) 33.35
Operative Temperature (°C) 33.17
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 46.45

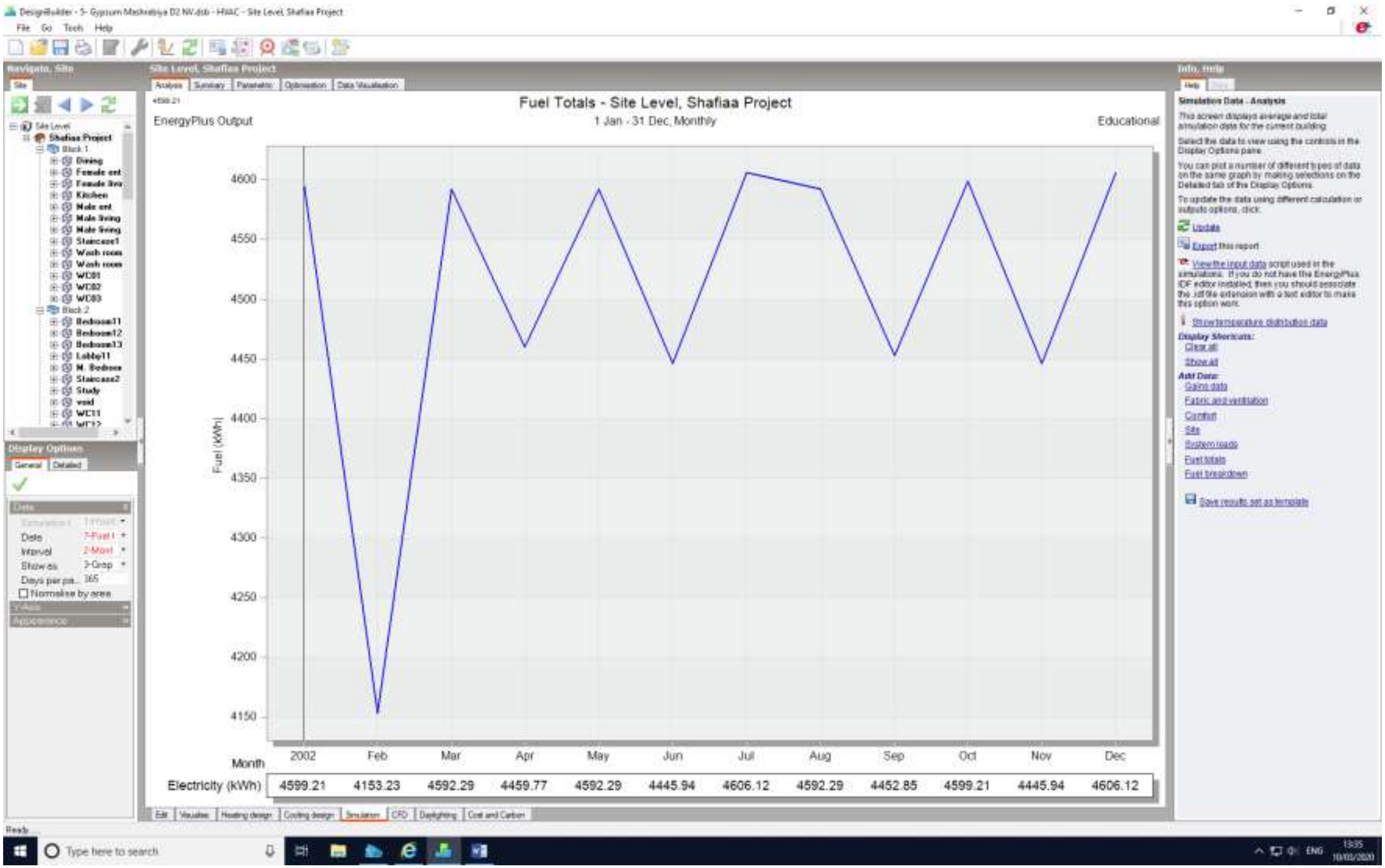

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Air Temperature (°C) 26.98 27.98 29.50 32.53 34.96 35.92 37.66 37.72 36.45 34.74 31.66 29.40
Radiant Temperature (°C) 27.23 28.28 29.84 32.96 35.28 36.32 37.99 38.08 36.90 35.17 32.07 29.73
Operative Temperature (°C) 27.11 28.13 29.67 32.74 35.12 36.12 37.82 37.90 36.67 34.96 31.86 29.57
Outside Dry-Bulb Temperature (°C) 22.79 23.57 25.04 27.63 30.57 31.01 33.16 33.13 31.41 29.87 26.87 25.05
Relative Humidity (%) 47.76 48.14 45.48 43.94 42.32 42.08 39.40 46.37 51.49 50.48 50.52 49.70

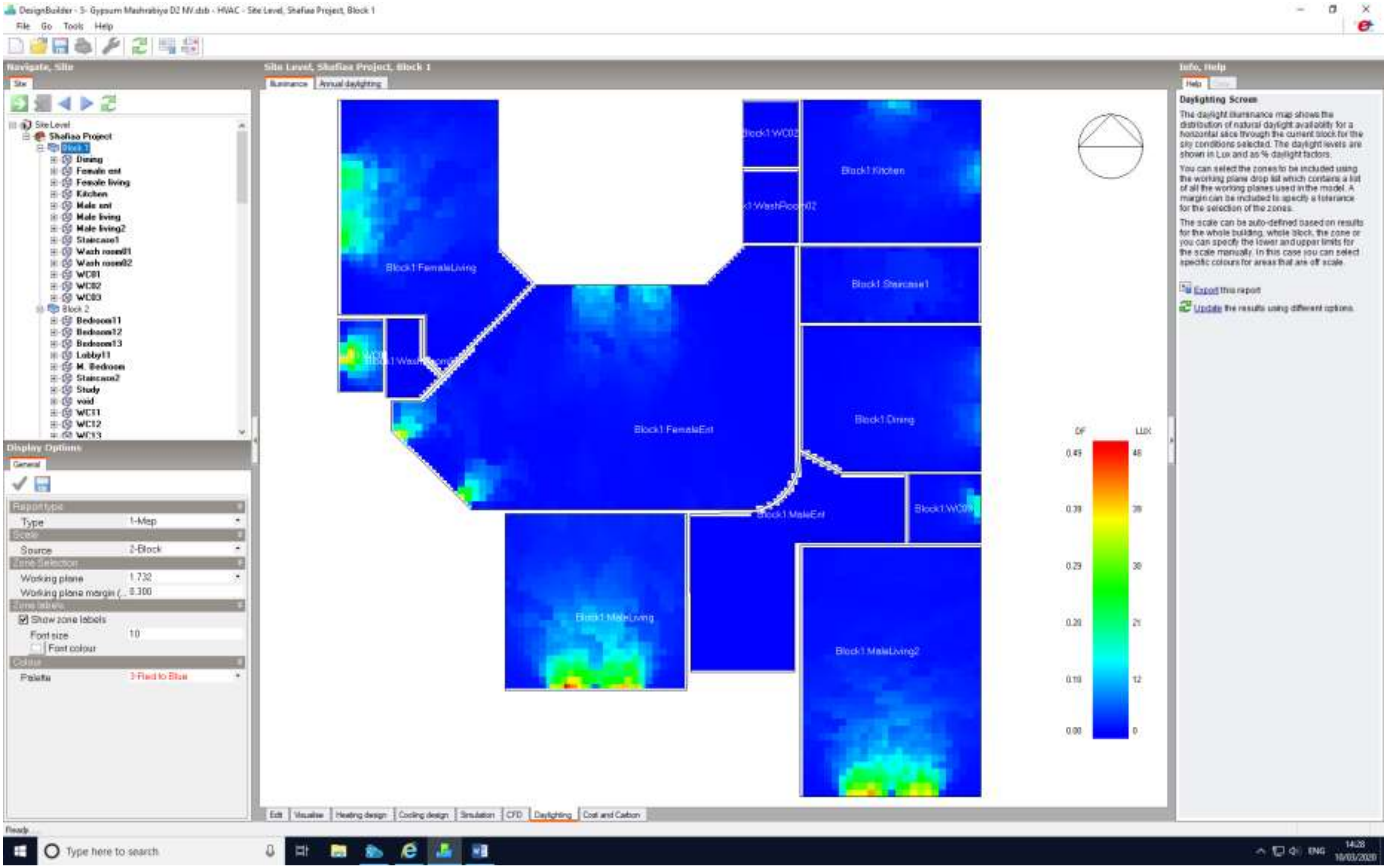

Fuel Breakdown - Site Level, Shafiaa Project
1 Jan - 31 Dec, Monthly
EnergyPlus Output
Educational
Lighting (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89

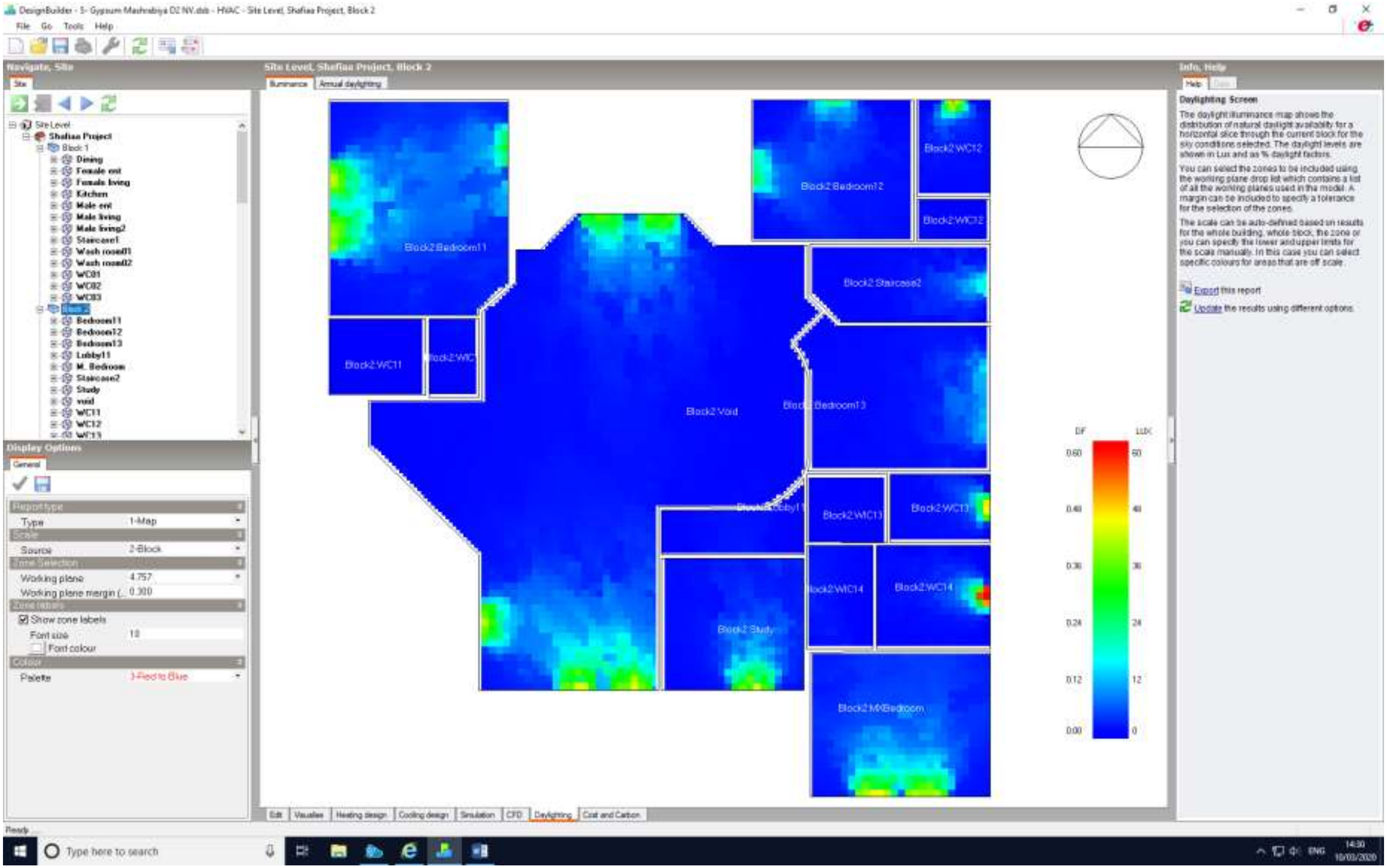


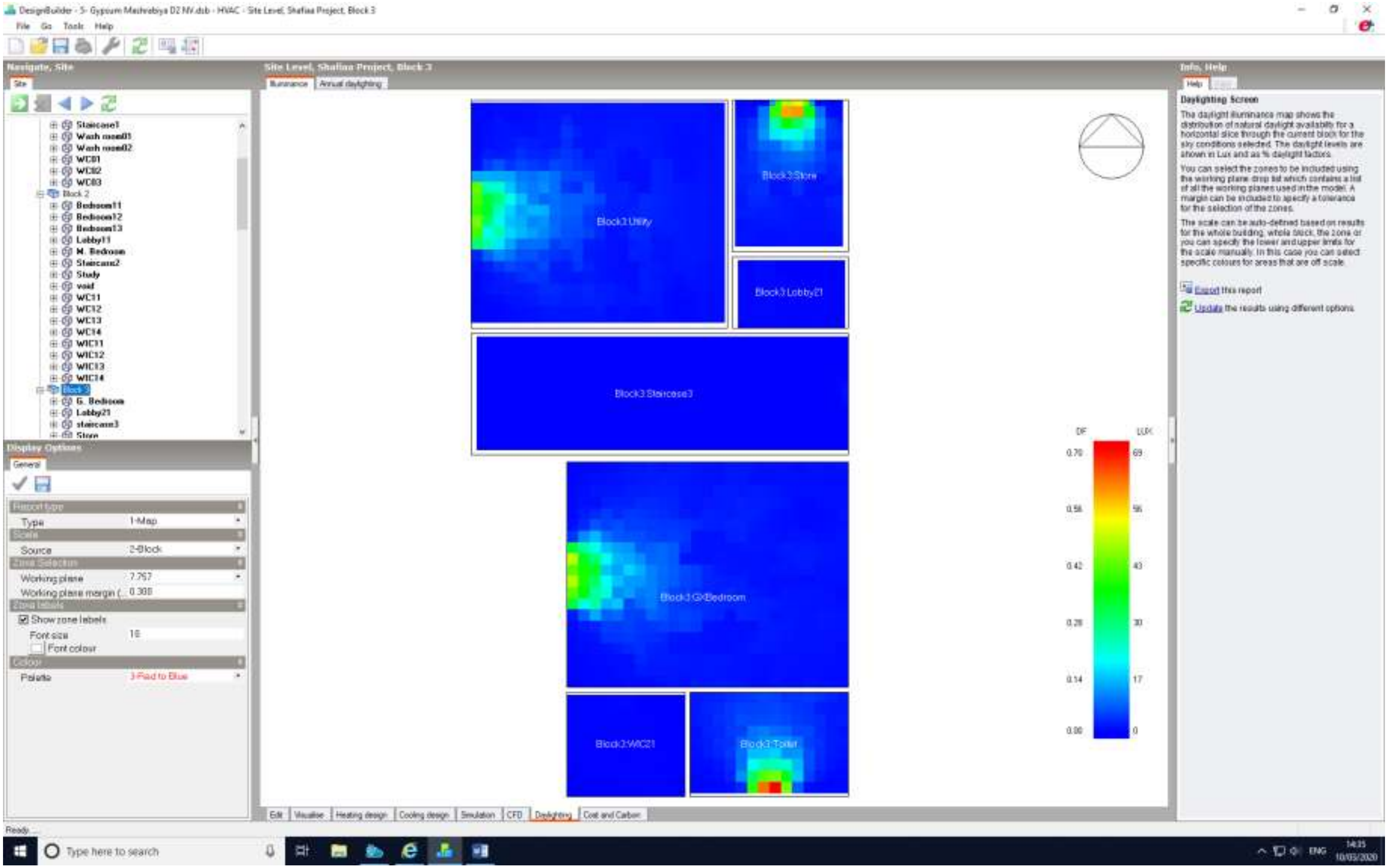
Fuel Breakdown - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Lighting (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Year
51308.96
2836.28


Fuel Totals - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Fuel (kWh)
60000
59000
58000
57000
56000
55000
54000
53000
52000
51000
50000
49000
Year
Electricity (kWh)
54145.25

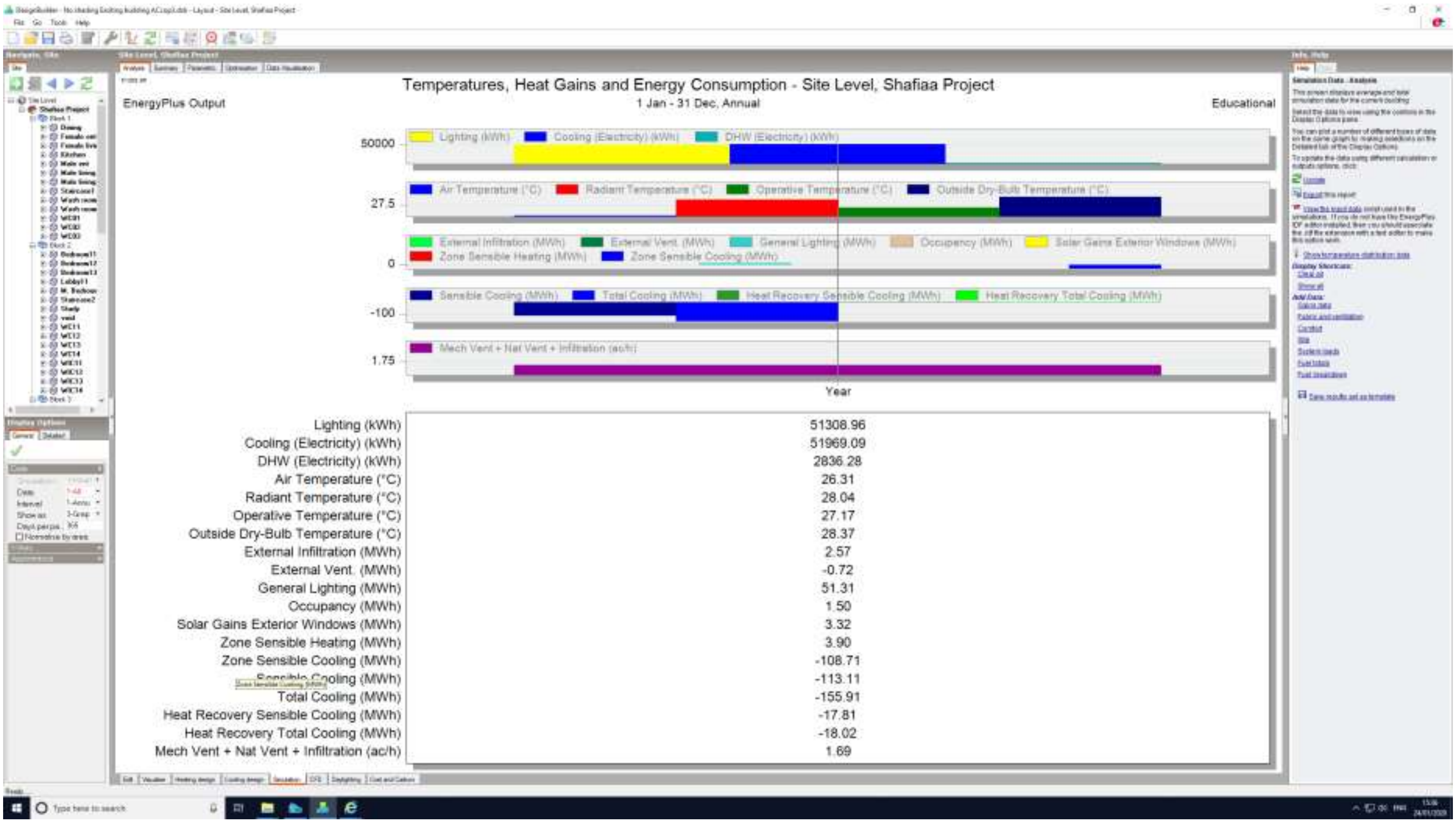

Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
4600
4550
4500
4450
4400
4350
4300
4250
4200
4150
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Electricity (kWh)
4599.21
4153.23
4592.29
4459.77
4592.29
4445.94
4606.12
4592.29
4452.85
4599.21
4445.94
4606.12

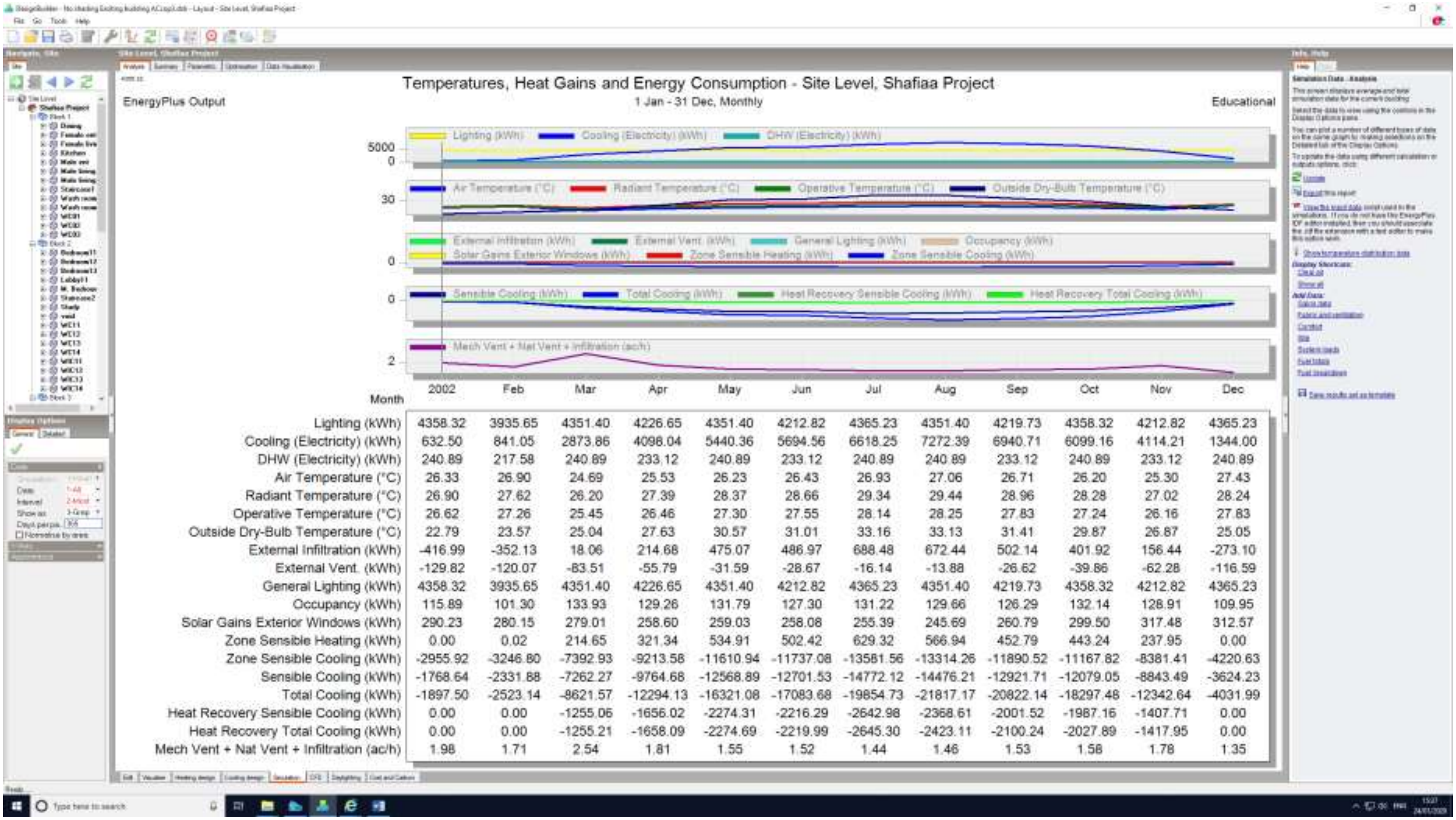



Site Level, Shafiaa Project, Block 2
Block2:Bedroom11
Block2:Bedroom12
Block2:WC12
Block2:Staircase2
Block2:WC11
Block2:Void
Block2:WC13
Block2:WC14
Block2:Study
Block2:MXBedroom
DF
LUX
0.60
0.48
0.36
0.24
0.12
0.00
60
48
36
24
12
0
Daylighting Screen

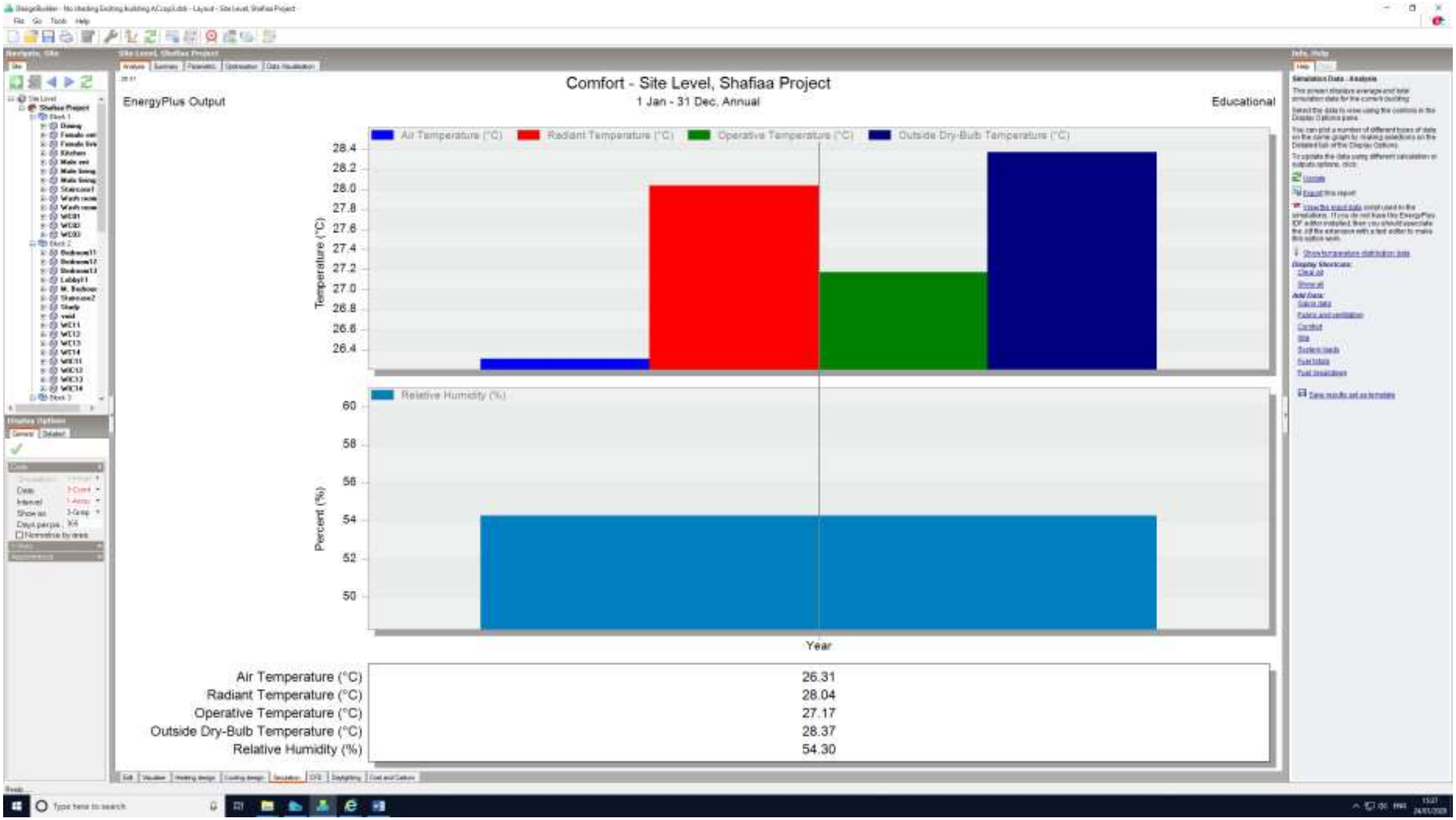

DesignBuilder - 5- Gypsum Mashrabiya D2 NV.dsb - HVAC - Site Level, Shafaa Project, Block 3
Navigate, Site
Site Level, Shafaa Project, Block 3
Info, Help
Block3:Utility
Block3:Store
Block3:Lobby21
Block3:Staircase3
Block3:GXBedroom
Block3:WC21
Block3:Toilet
DF
LUX
Daylighting Screen
Export this report
Update the results using different options
Display Options
Show zone labels
Font size
Font colour
Palette
Working plane
Working plane margin
Type
Source

6- Existing Villa with AC

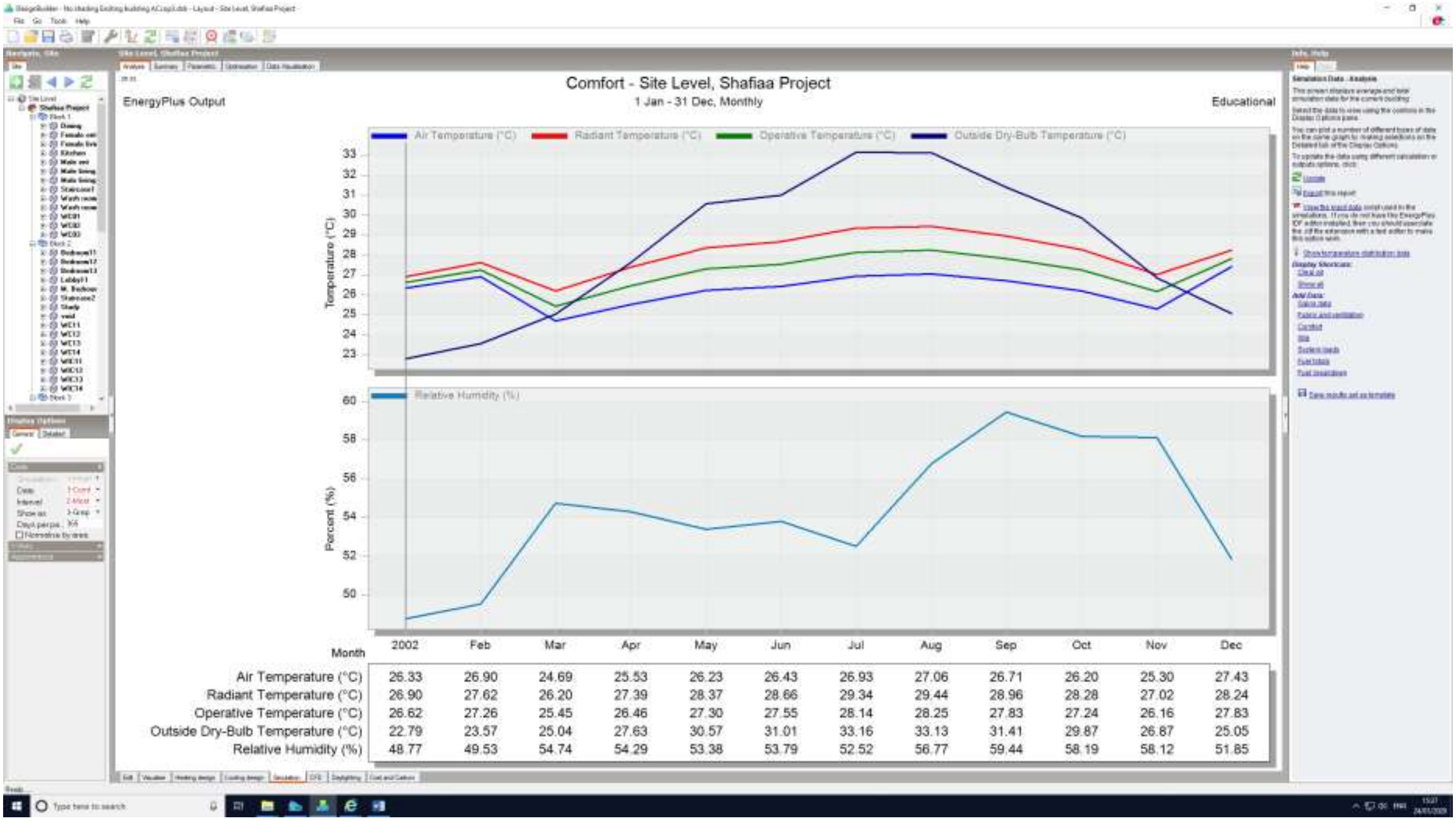


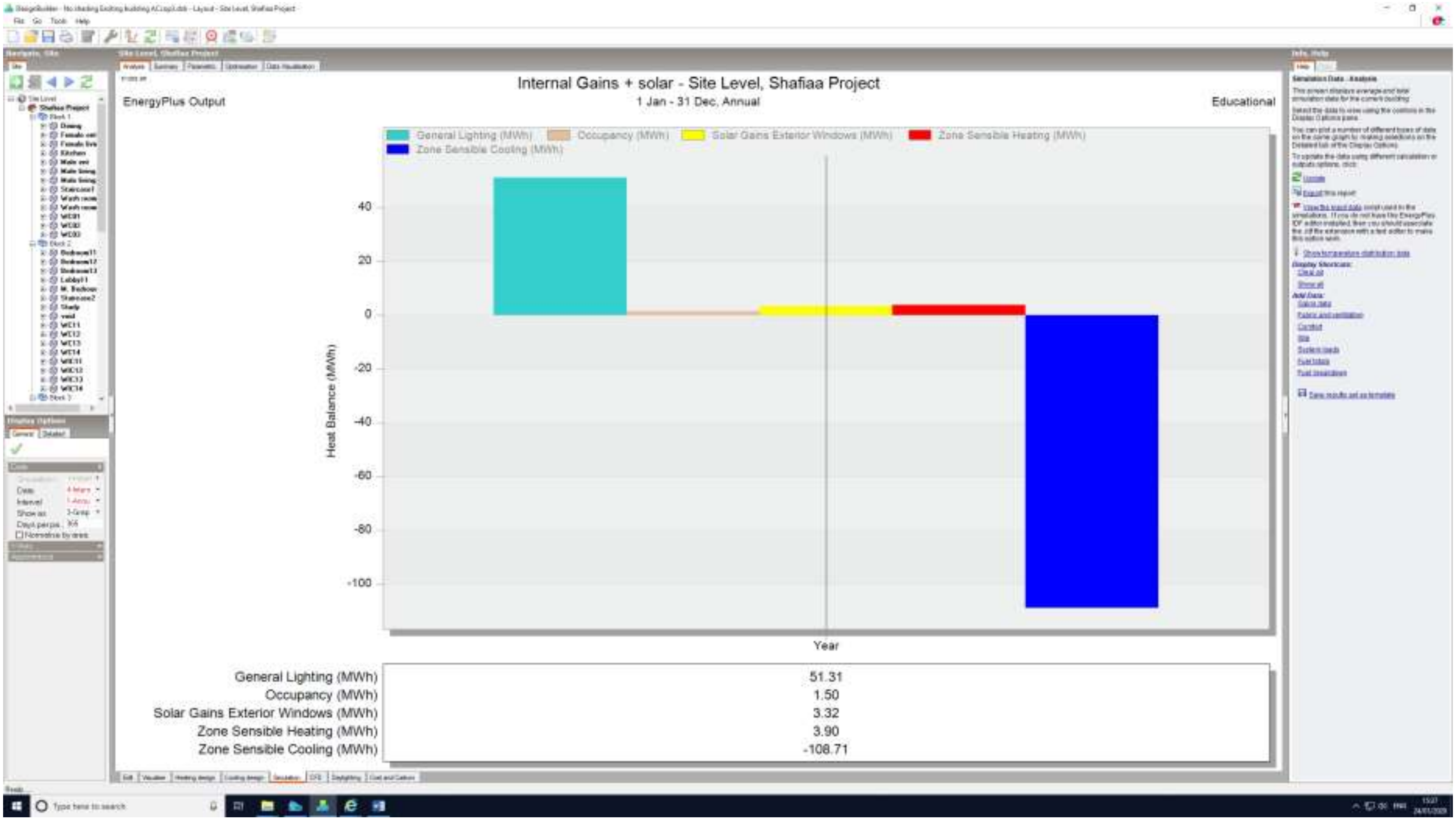


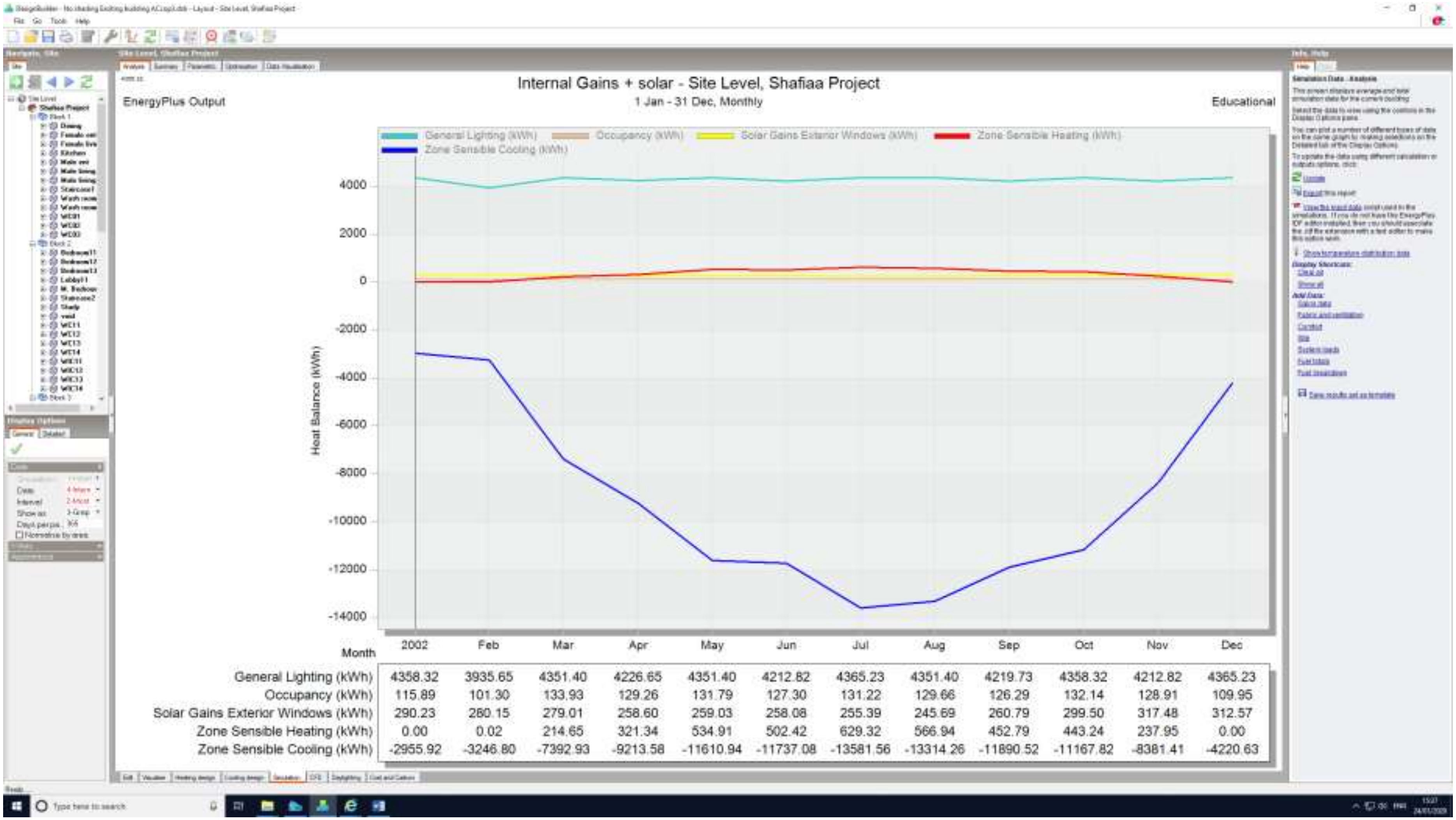
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Cooling (Electricity) (kWh)	632.50	841.05	2873.86	4098.04	5440.36	5694.56	6618.25	7272.39	6940.71	6099.16	4114.21	1344.00
DHW (Electricity) (kWh)	240.89	217.58	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89
Air Temperature (°C)	26.33	26.90	24.69	25.53	26.23	26.43	26.93	27.06	26.71	26.20	25.30	27.43
Radiant Temperature (°C)	26.90	27.62	26.20	27.39	28.37	28.66	29.34	29.44	28.96	28.28	27.02	28.24
Operative Temperature (°C)	26.62	27.26	25.45	26.46	27.30	27.55	28.14	28.25	27.83	27.24	26.16	27.83
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-416.99	-352.13	18.06	214.68	475.07	486.97	688.48	672.44	502.14	401.92	156.44	-273.10
External Vent. (kWh)	-129.82	-120.07	-83.51	-55.79	-31.59	-28.67	-16.14	-13.88	-26.62	-39.86	-62.28	-116.59
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Occupancy (kWh)	115.89	101.30	133.93	129.26	131.79	127.30	131.22	129.66	126.29	132.14	128.91	109.95
Solar Gains Exterior Windows (kWh)	290.23	280.15	279.01	258.60	259.03	258.08	255.39	245.69	260.79	299.50	317.48	312.57
Zone Sensible Heating (kWh)	0.00	0.02	214.65	321.34	534.91	502.42	629.32	566.94	452.79	443.24	237.95	0.00
Zone Sensible Cooling (kWh)	-2955.92	-3246.80	-7392.93	-9213.58	-11610.94	-11737.08	-13581.56	-13314.26	-11890.52	-11167.82	-8381.41	-4220.63
Sensible Cooling (kWh)	-1768.64	-2331.88	-7262.27	-9764.68	-12568.89	-12701.53	-14772.12	-14476.21	-12921.71	-12079.05	-8843.49	-3624.23
Total Cooling (kWh)	-1897.50	-2523.14	-8621.57	-12294.13	-16321.08	-17083.68	-19854.73	-21817.17	-20822.14	-18297.48	-12342.64	-4031.99
Heat Recovery Sensible Cooling (kWh)	0.00	0.00	-1255.06	-1656.02	-2274.31	-2216.29	-2642.98	-2368.61	-2001.52	-1987.16	-1407.71	0.00
Heat Recovery Total Cooling (kWh)	0.00	0.00	-1255.21	-1658.09	-2274.69	-2219.99	-2645.30	-2423.11	-2100.24	-2027.89	-1417.95	0.00
Mech Vent + Nat Vent + Infiltration (ac/h)	1.98	1.71	2.54	1.81	1.55	1.52	1.44	1.46	1.53	1.58	1.78	1.35



Comfort - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Year
Air Temperature (°C) 26.31
Radiant Temperature (°C) 28.04
Operative Temperature (°C) 27.17
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 54.30

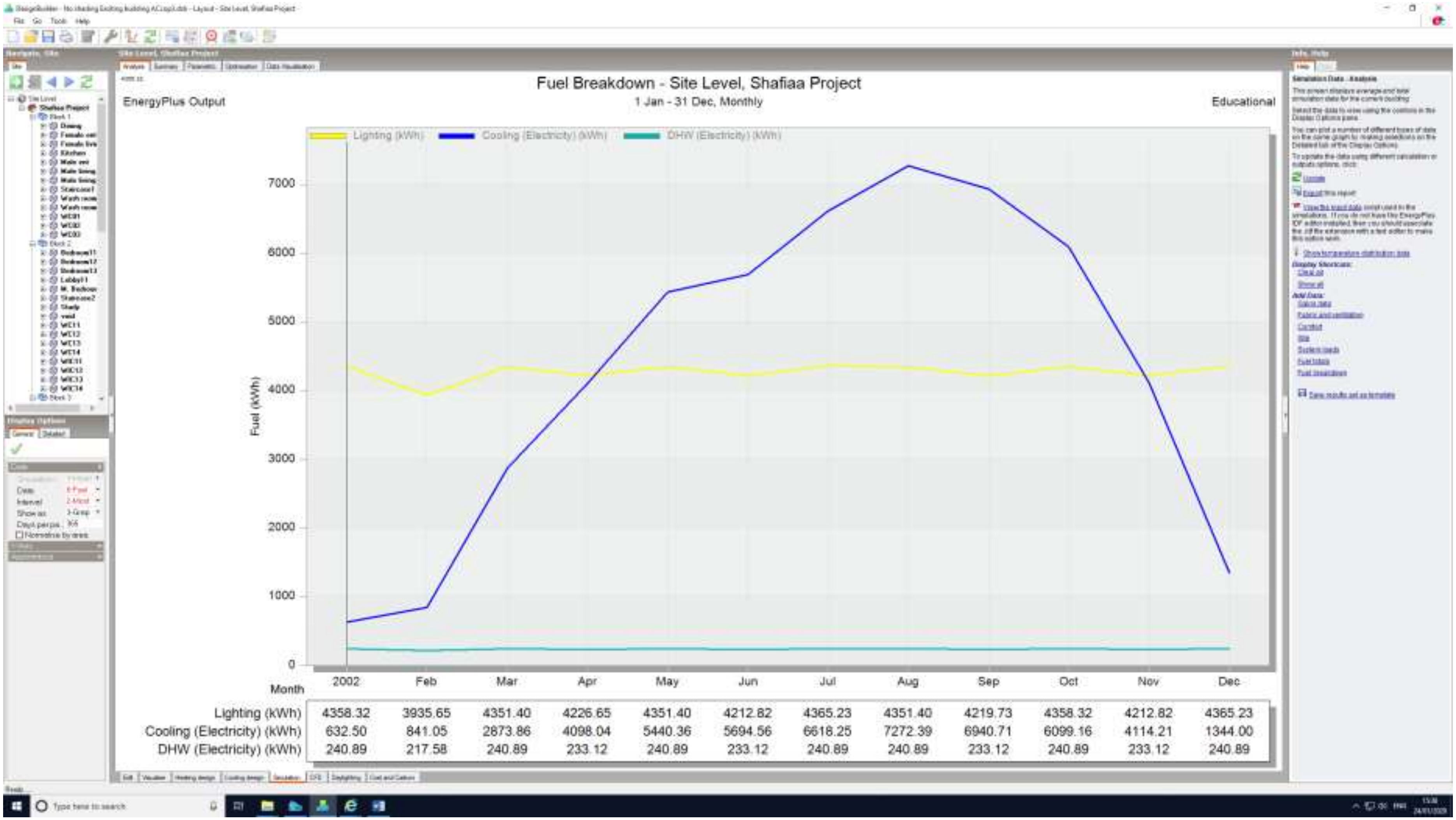

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Air Temperature (°C) 26.33 26.90 24.69 25.53 26.23 26.43 26.93 27.06 26.71 26.20 25.30 27.43
Radiant Temperature (°C) 26.90 27.62 26.20 27.39 28.37 28.66 29.34 29.44 28.96 28.28 27.02 28.24
Operative Temperature (°C) 26.62 27.26 25.45 26.46 27.30 27.55 28.14 28.25 27.83 27.24 26.16 27.83
Outside Dry-Bulb Temperature (°C) 22.79 23.57 25.04 27.63 30.57 31.01 33.16 33.13 31.41 29.87 26.87 25.05
Relative Humidity (%) 48.77 49.53 54.74 54.29 53.38 53.79 52.52 56.77 59.44 58.19 58.12 51.85

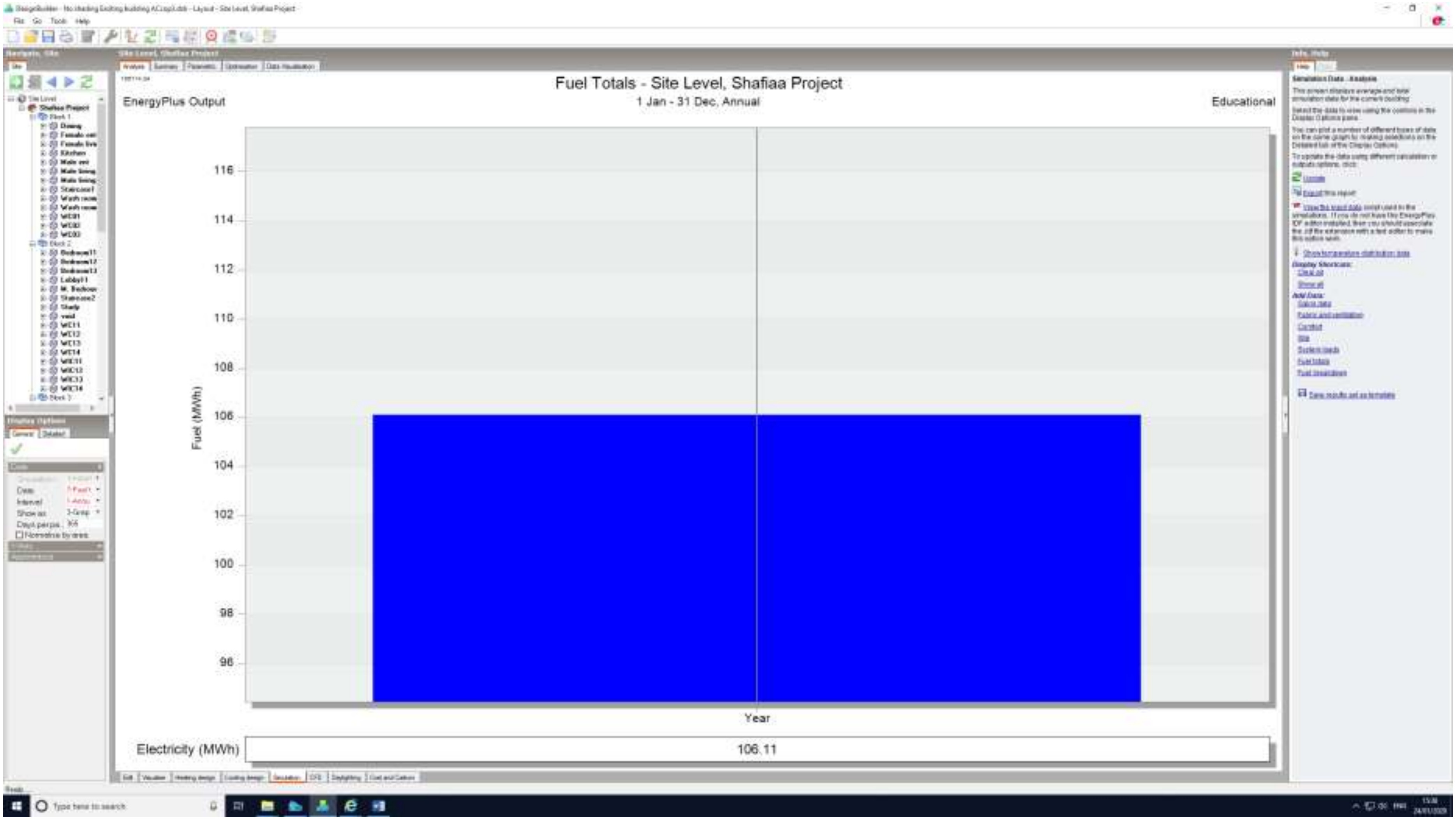

Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
General Lighting (MWh)
Occupancy (MWh)
Solar Gains Exterior Windows (MWh)
Zone Sensible Heating (MWh)
Zone Sensible Cooling (MWh)
Heat Balance (MWh)
40
20
0
-20
-40
-60
-80
-100
Year
General Lighting (MWh) 51.31
Occupancy (MWh) 1.50
Solar Gains Exterior Windows (MWh) 3.32
Zone Sensible Heating (MWh) 3.90
Zone Sensible Cooling (MWh) -108.71

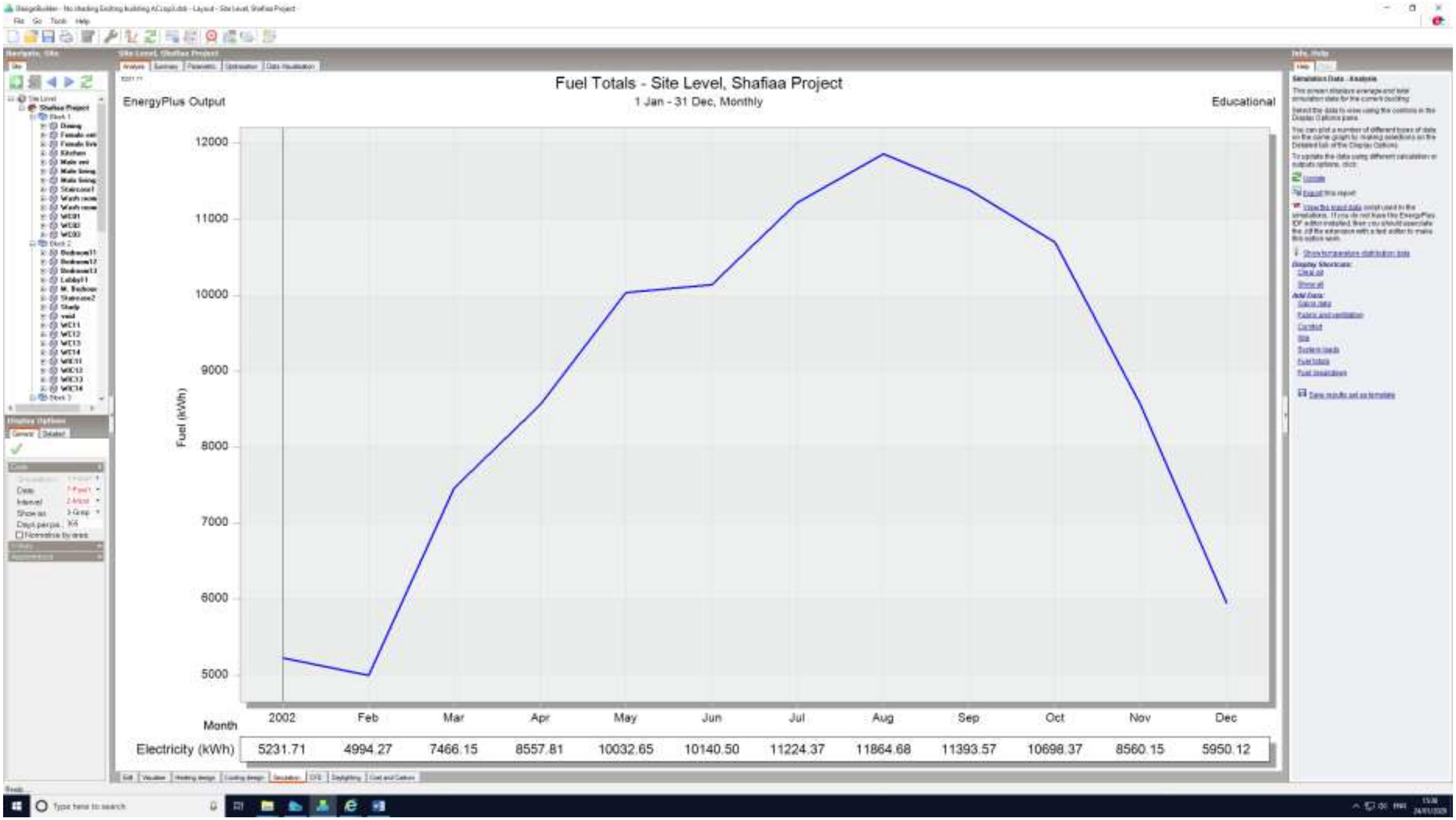


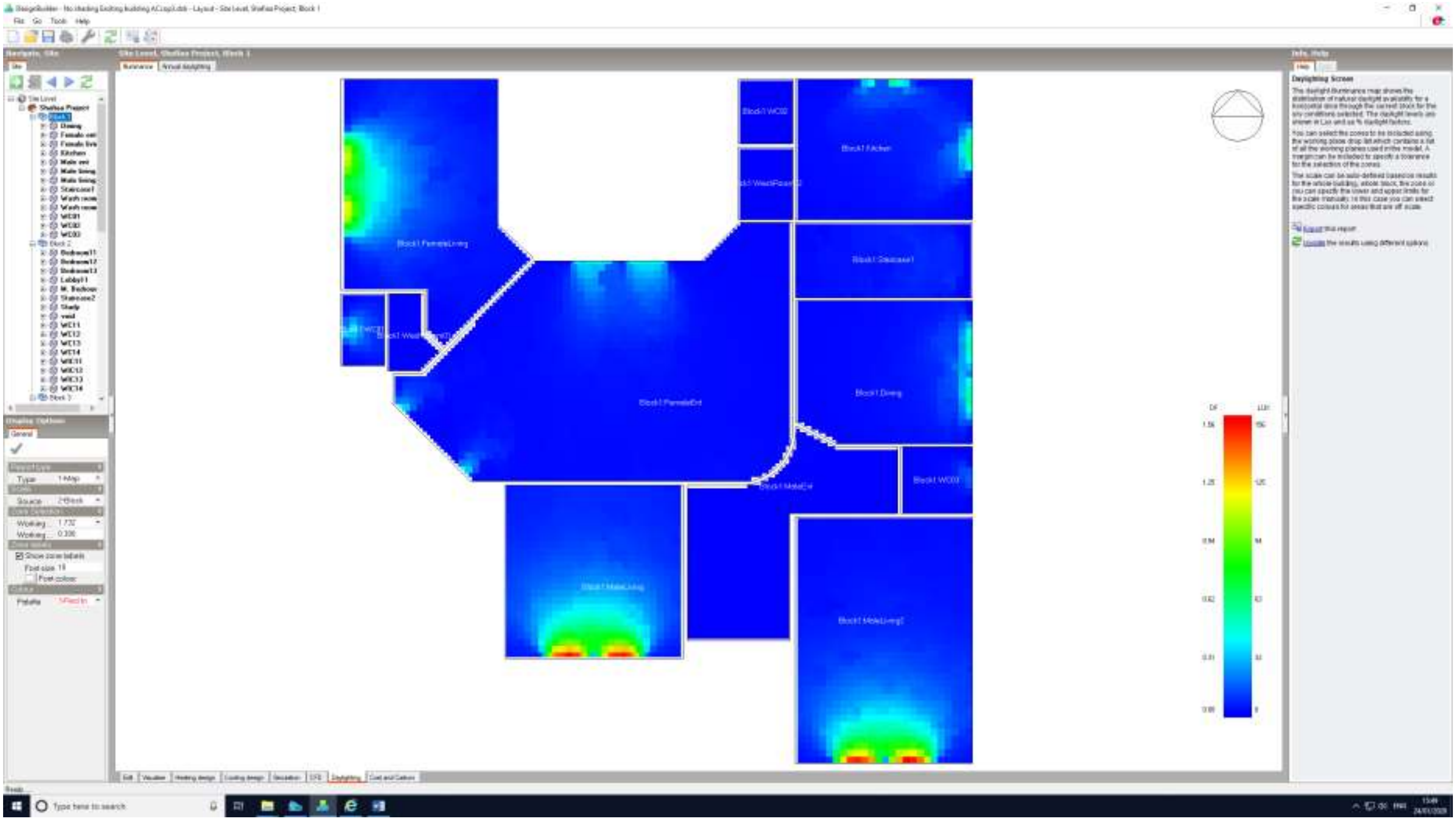
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Occupancy (kWh)	115.89	101.30	133.93	129.26	131.79	127.30	131.22	129.66	126.29	132.14	128.91	109.95
Solar Gains Exterior Windows (kWh)	290.23	280.15	279.01	258.60	259.03	258.08	255.39	245.69	260.79	299.50	317.48	312.57
Zone Sensible Heating (kWh)	0.00	0.02	214.65	321.34	534.91	502.42	629.32	566.94	452.79	443.24	237.95	0.00
Zone Sensible Cooling (kWh)	-2955.92	-3246.80	-7392.93	-9213.58	-11610.94	-11737.08	-13581.56	-13314.26	-11890.52	-11167.82	-8381.41	-4220.63

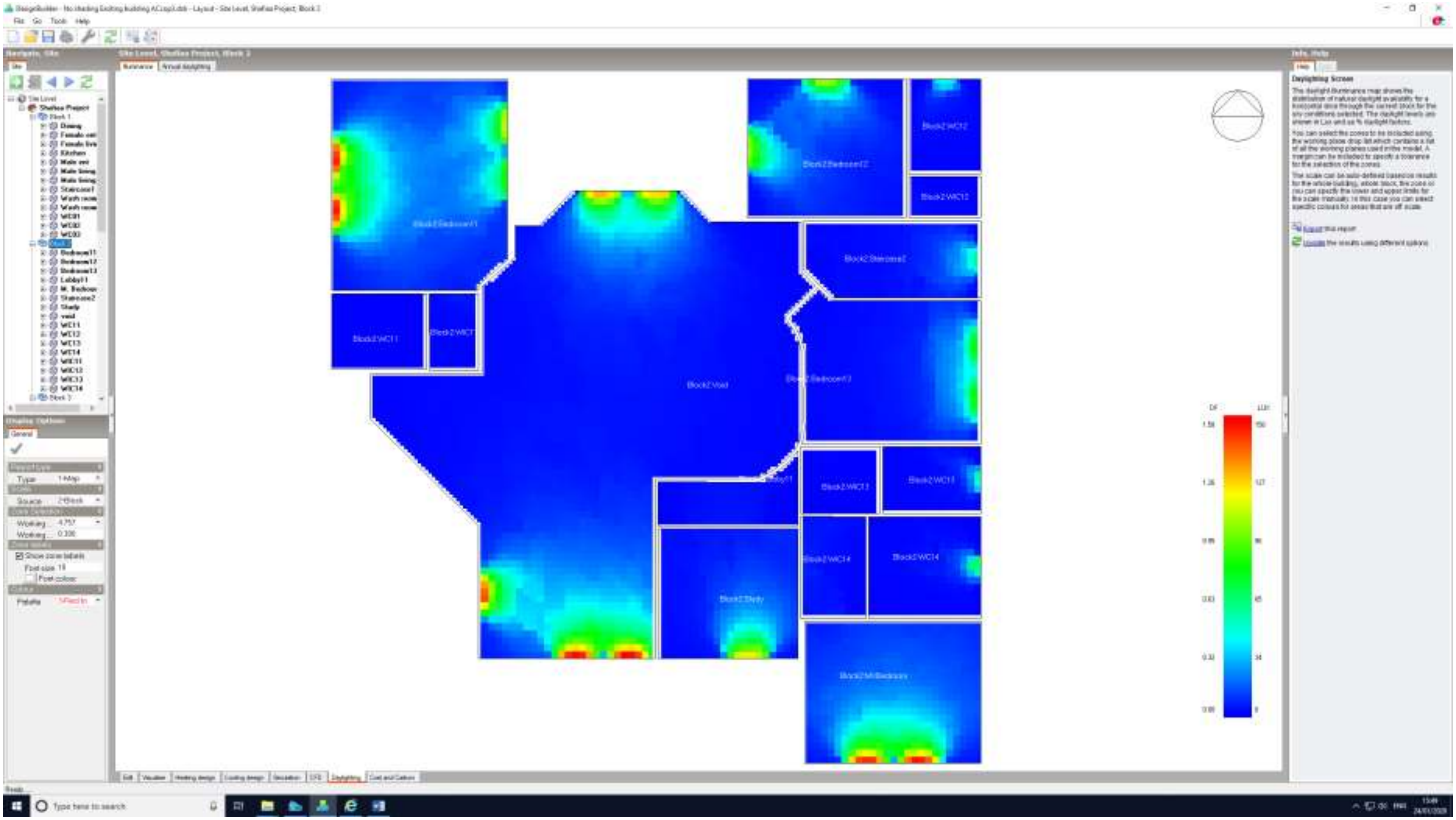

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Year
Lighting (kWh) 51308.96
Cooling (Electricity) (kWh) 51969.09
DHW (Electricity) (kWh) 2836.28

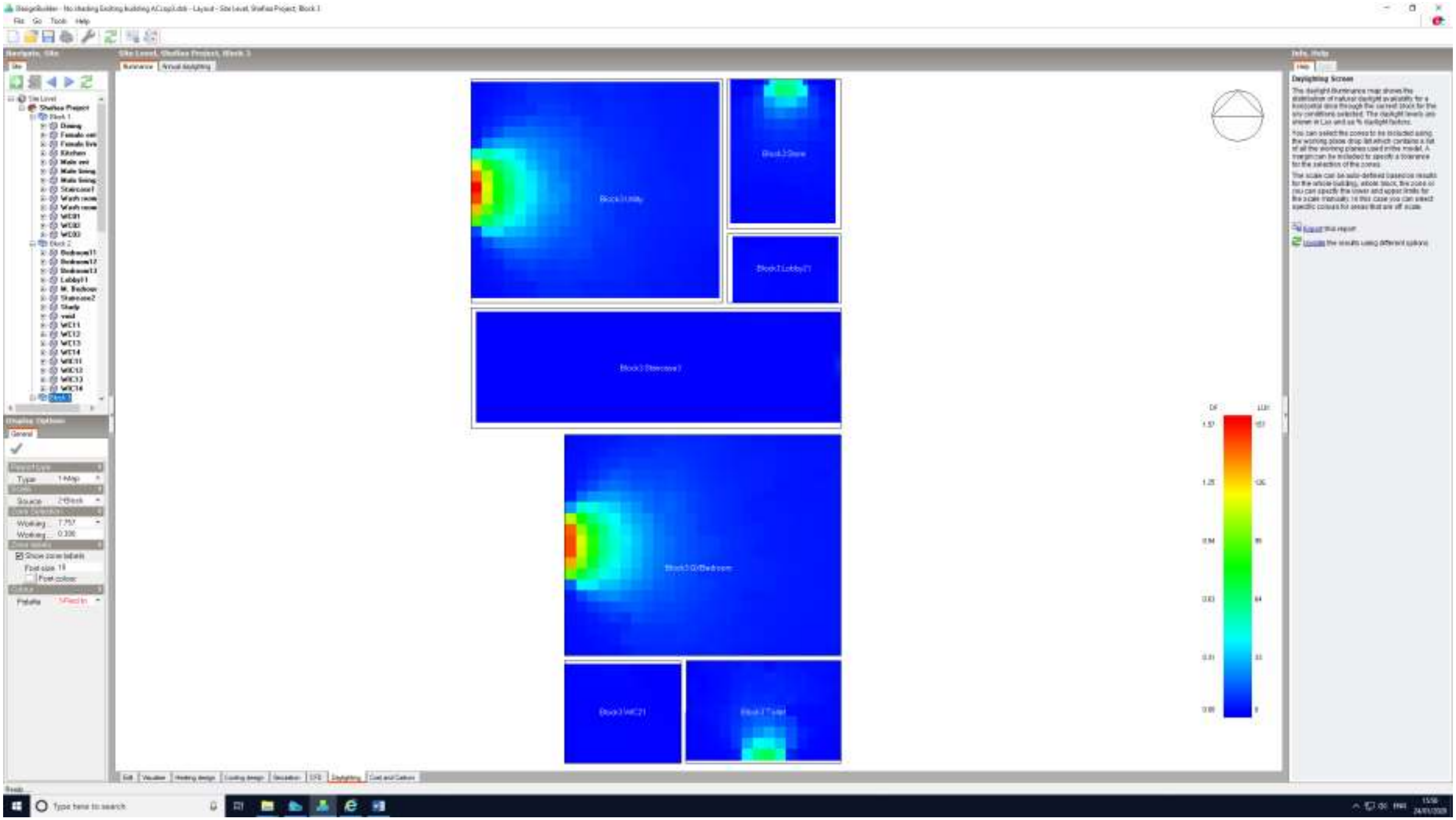

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
7000
6000
5000
4000
3000
2000
1000
0
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
Cooling (Electricity) (kWh) 632.50 841.05 2873.86 4098.04 5440.36 5694.56 6618.25 7272.39 6940.71 6099.16 4114.21 1344.00
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89


Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
116
114
112
110
108
106
104
102
100
98
96
Fuel (MWh)
Year
Electricity (MWh)
106.11

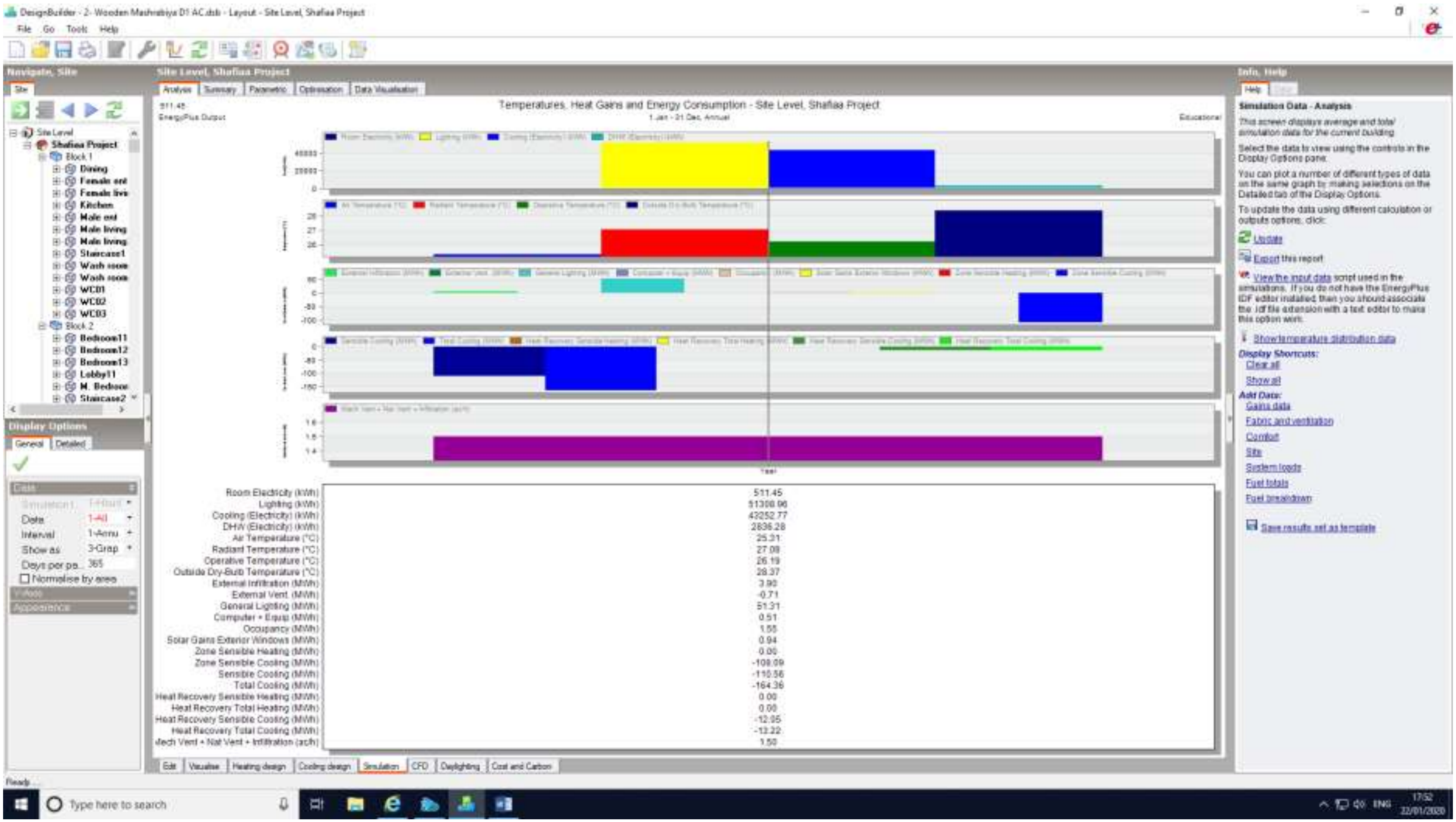

Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
12000
11000
10000
9000
8000
7000
6000
5000
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Electricity (kWh)
5231.71
4994.27
7466.15
8557.81
10032.65
10140.50
11224.37
11864.68
11393.57
10698.37
8560.15
5950.12

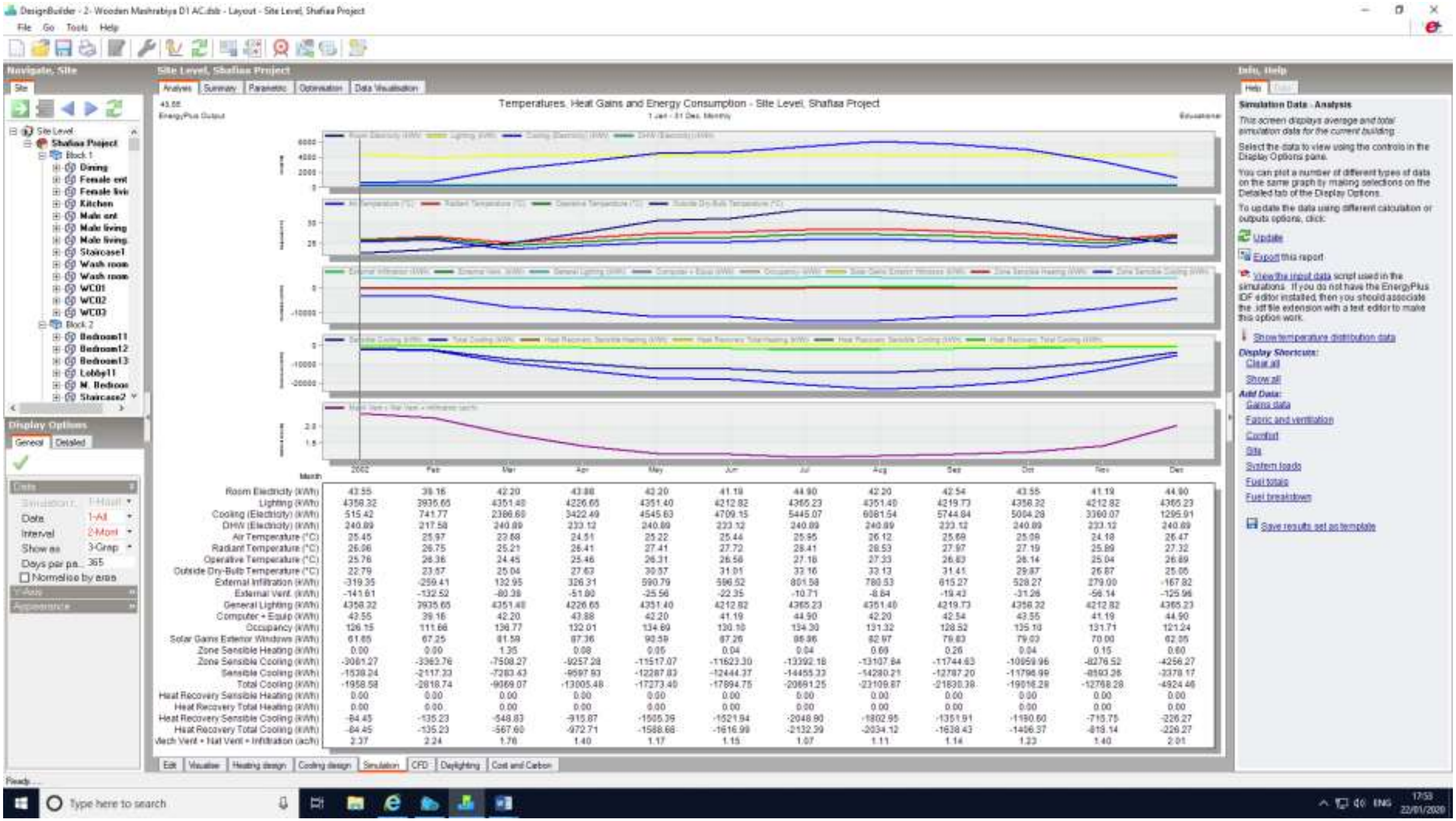

Block1 FemaleLiving
Block1 WC02
Block1 Kitchen
Block1 Staircase1
Block1 FemaleEnt
Block1 Dining
Block1 MaleEnt
Block1 WC03
Block1 MaleLiving
Block1 MaleLiving2
DF
LUX

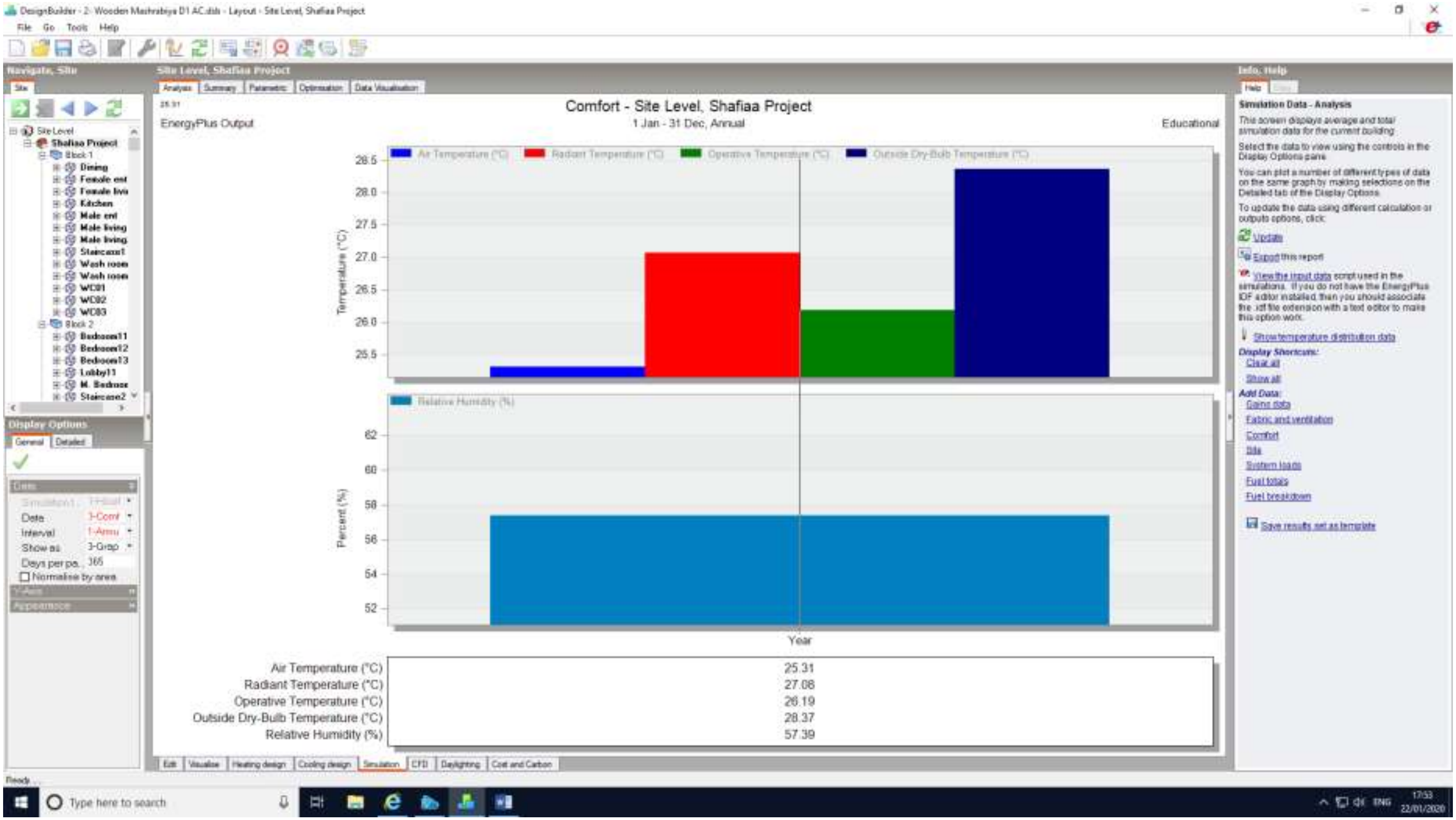


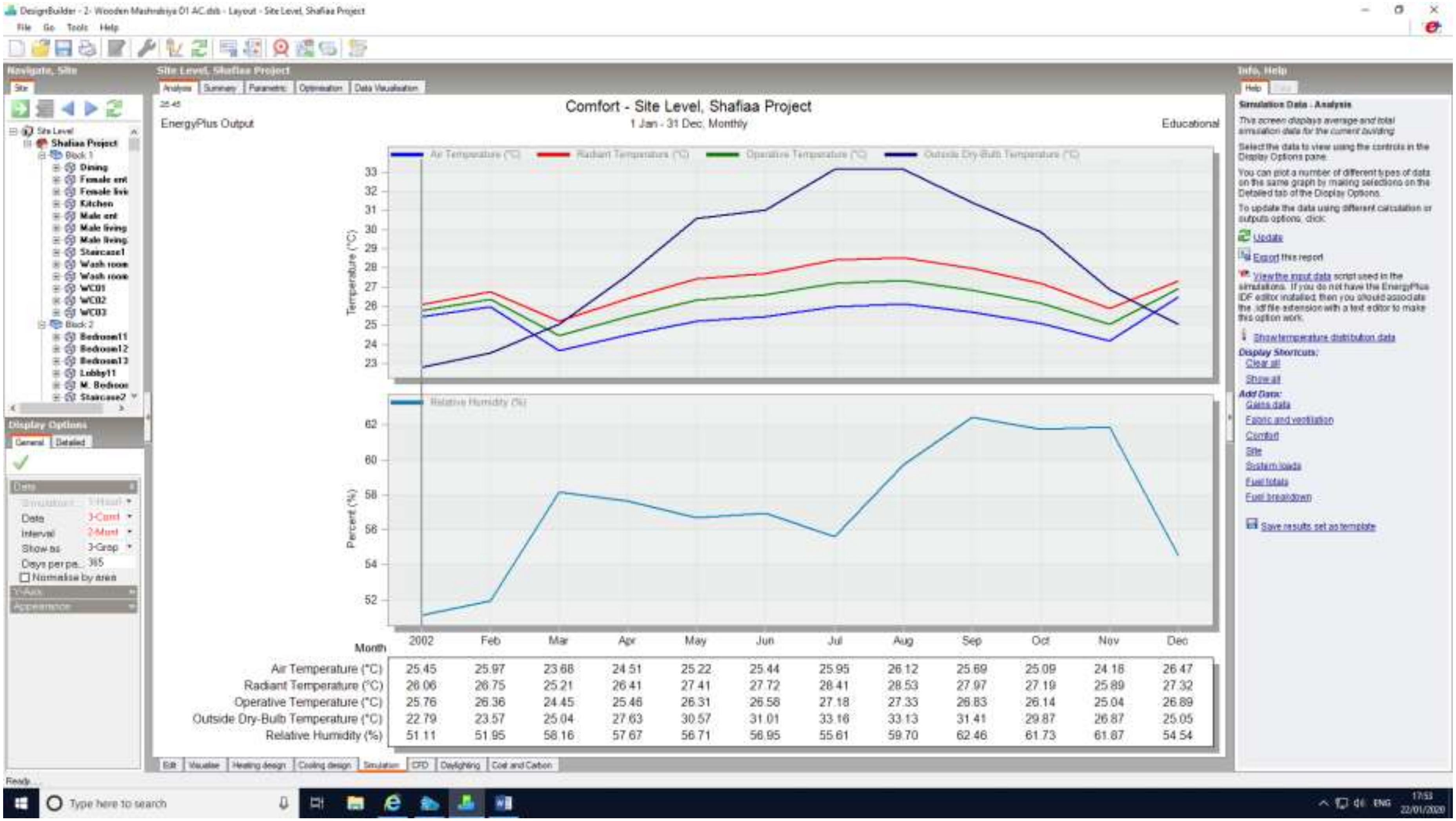


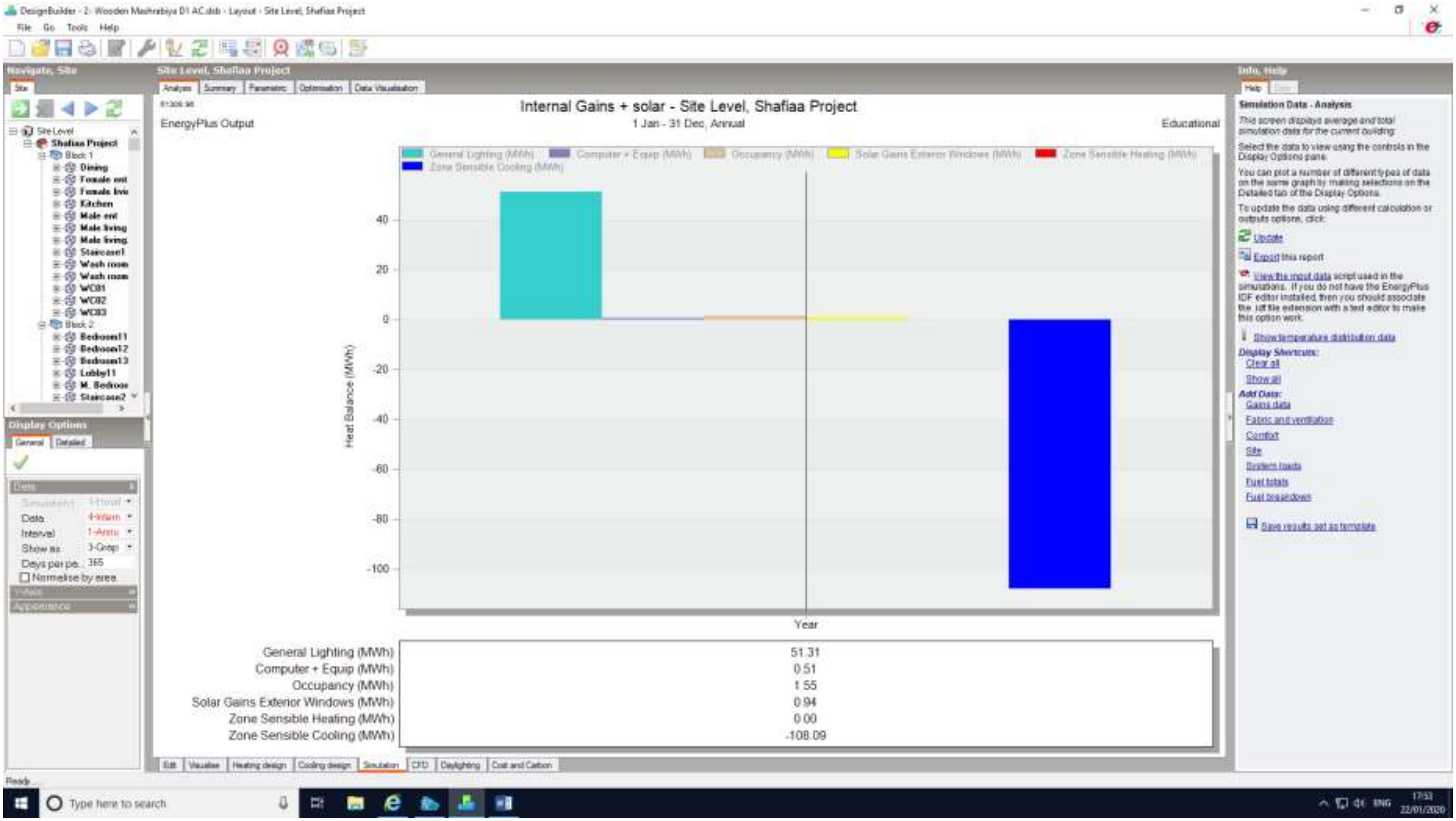
7- Wooden mashrabiya D1 with AC

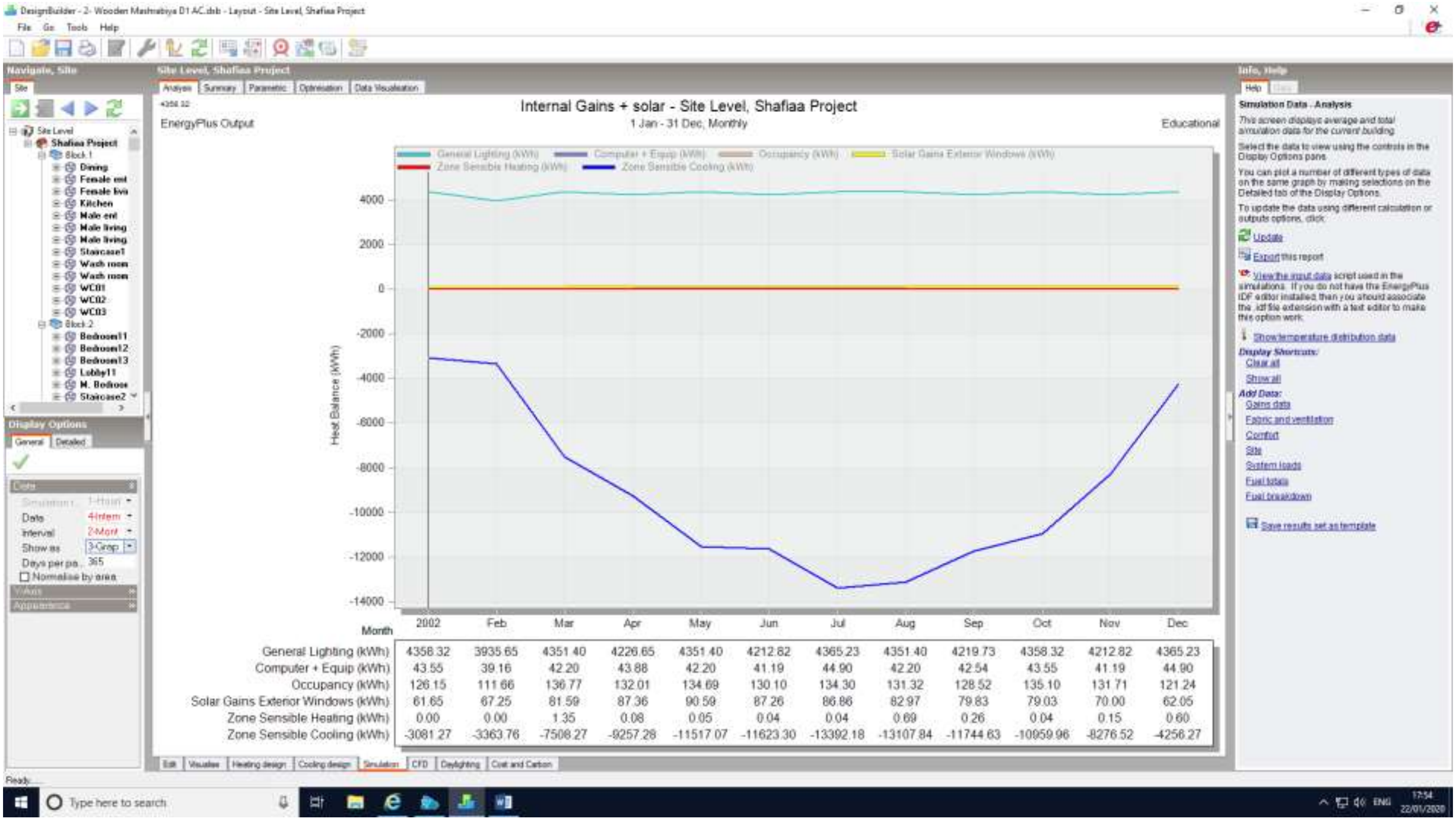



DesignBuilder - 2- Wooden Mashrabiya D1 AC.dsb - Layout - Site Level, Shafiaa Project
File Go Tools Help
Navigate, Site
Site Level, Shafiaa Project
Analysis Summary Parametric Optimisation Data Visualisation
Temperatures, Heat Gains and Energy Consumption - Site Level, Shafiaa Project
1 Jan - 31 Dec, Monthly
Info, Help
Simulation Data - Analysis
This screen displays average and total simulation data for the current building
Select the data to view using the controls in the Display Options pane.
Display Options
General Detailed
Edit Visualise Heating design Cooling design Simulation CFD Daylighting Cost and Carbon

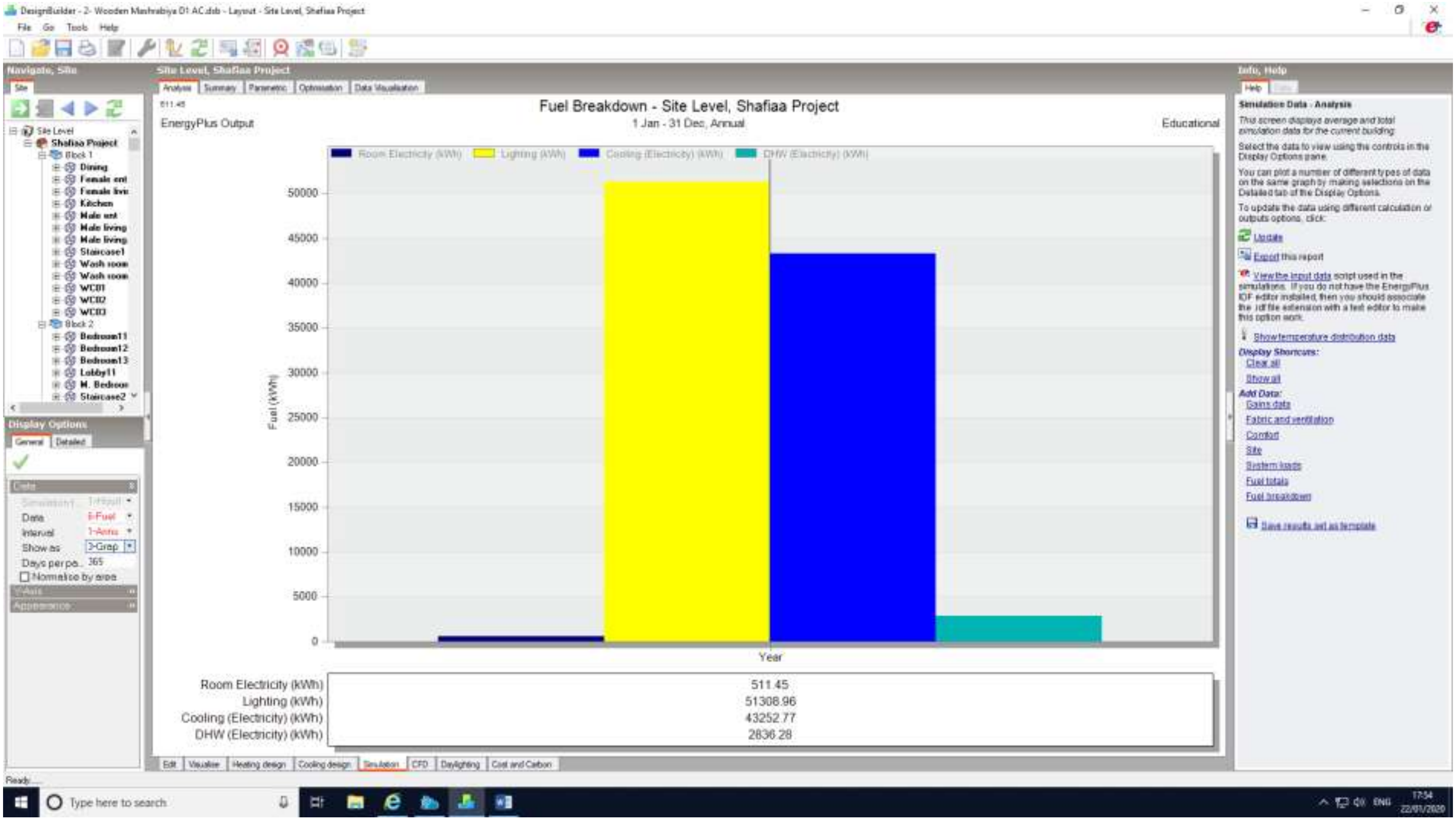

Comfort - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Relative Humidity (%)
Temperature (°C)
Percent (%)
Year
Air Temperature (°C) 25.31
Radiant Temperature (°C) 27.08
Operative Temperature (°C) 26.19
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 57.39

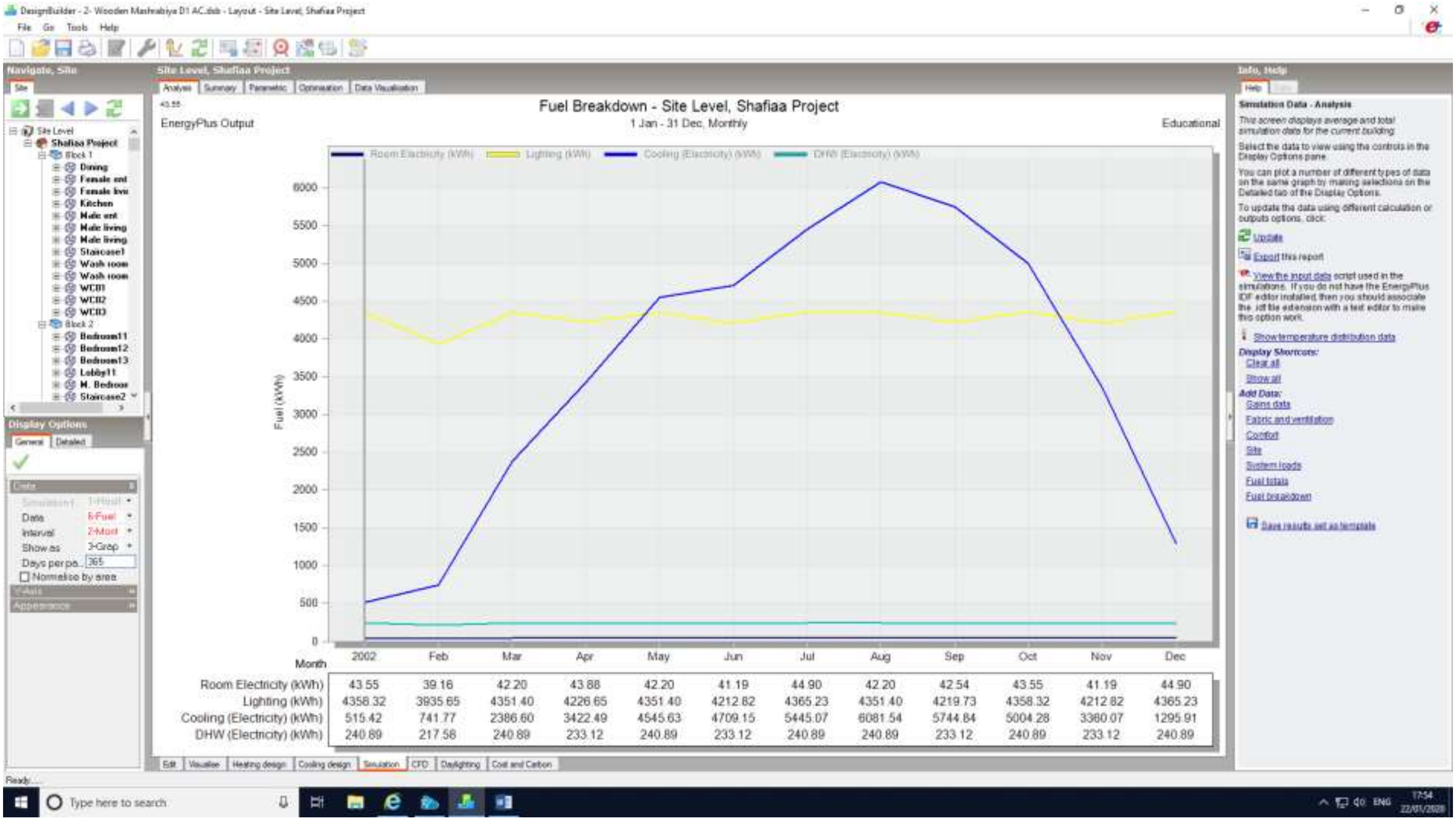

Comfort - Site Level, Shafiaa Project
1 Jan - 31 Dec, Monthly
EnergyPlus Output
Educational
Temperature (°C)
Percent (%)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Air Temperature (°C) 25.45 25.97 23.68 24.51 25.22 25.44 25.95 26.12 25.69 25.09 24.18 26.47
Radiant Temperature (°C) 26.06 26.75 25.21 26.41 27.41 27.72 28.41 28.53 27.97 27.19 25.89 27.32
Operative Temperature (°C) 25.76 26.36 24.45 25.46 26.31 26.58 27.18 27.33 26.83 26.14 25.04 26.89
Outside Dry-Bulb Temperature (°C) 22.79 23.57 25.04 27.63 30.57 31.01 33.16 33.13 31.41 29.87 26.87 25.05
Relative Humidity (%) 51.11 51.95 58.16 57.67 56.71 56.95 55.61 59.70 62.46 61.73 61.87 54.54

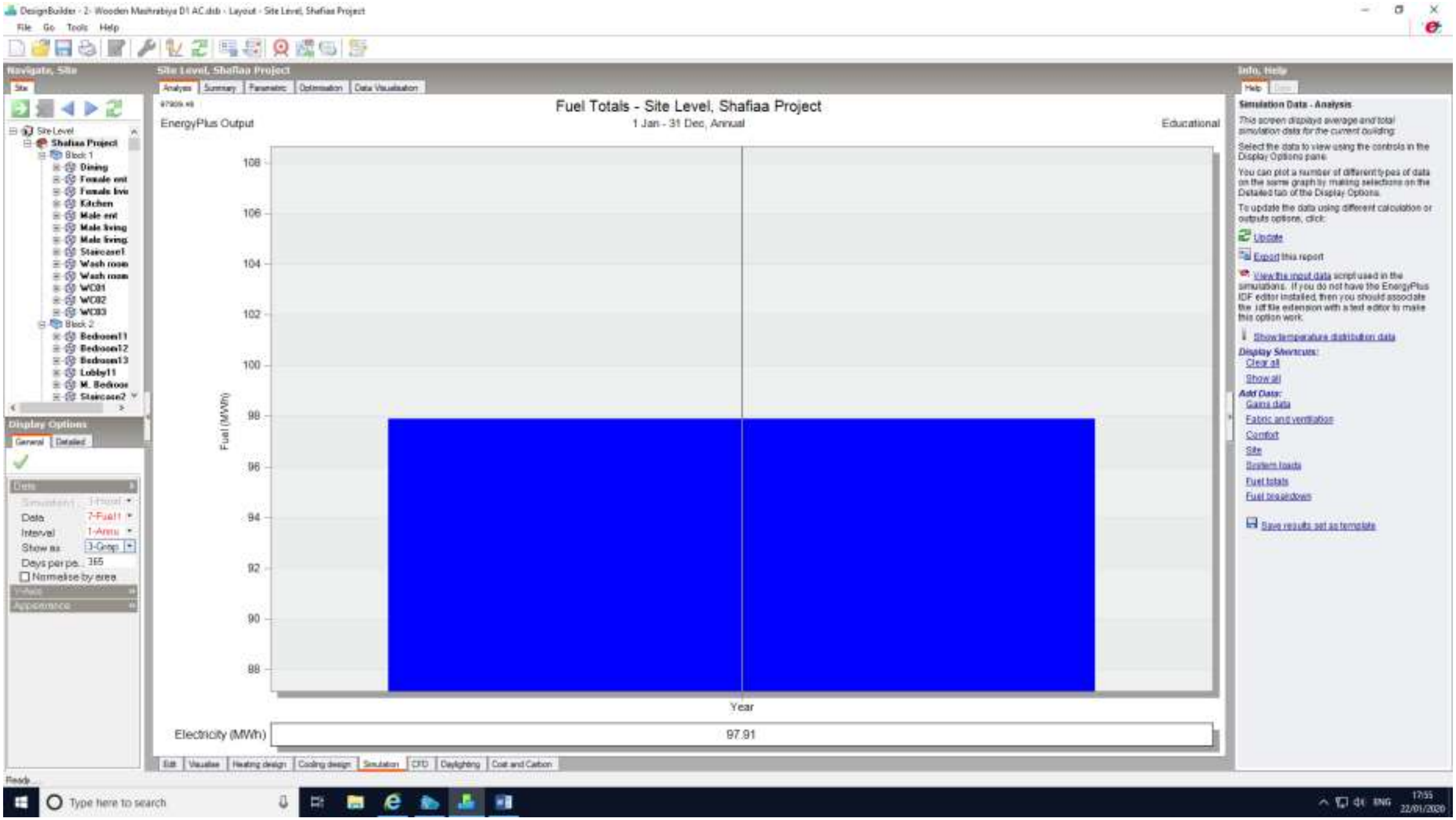

Internal Gains + solar - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Heat Balance (MWh)
Year
General Lighting (MWh) 51.31
Computer + Equip (MWh) 0.51
Occupancy (MWh) 1.55
Solar Gains Exterior Windows (MWh) 0.94
Zone Sensible Heating (MWh) 0.00
Zone Sensible Cooling (MWh) -108.09

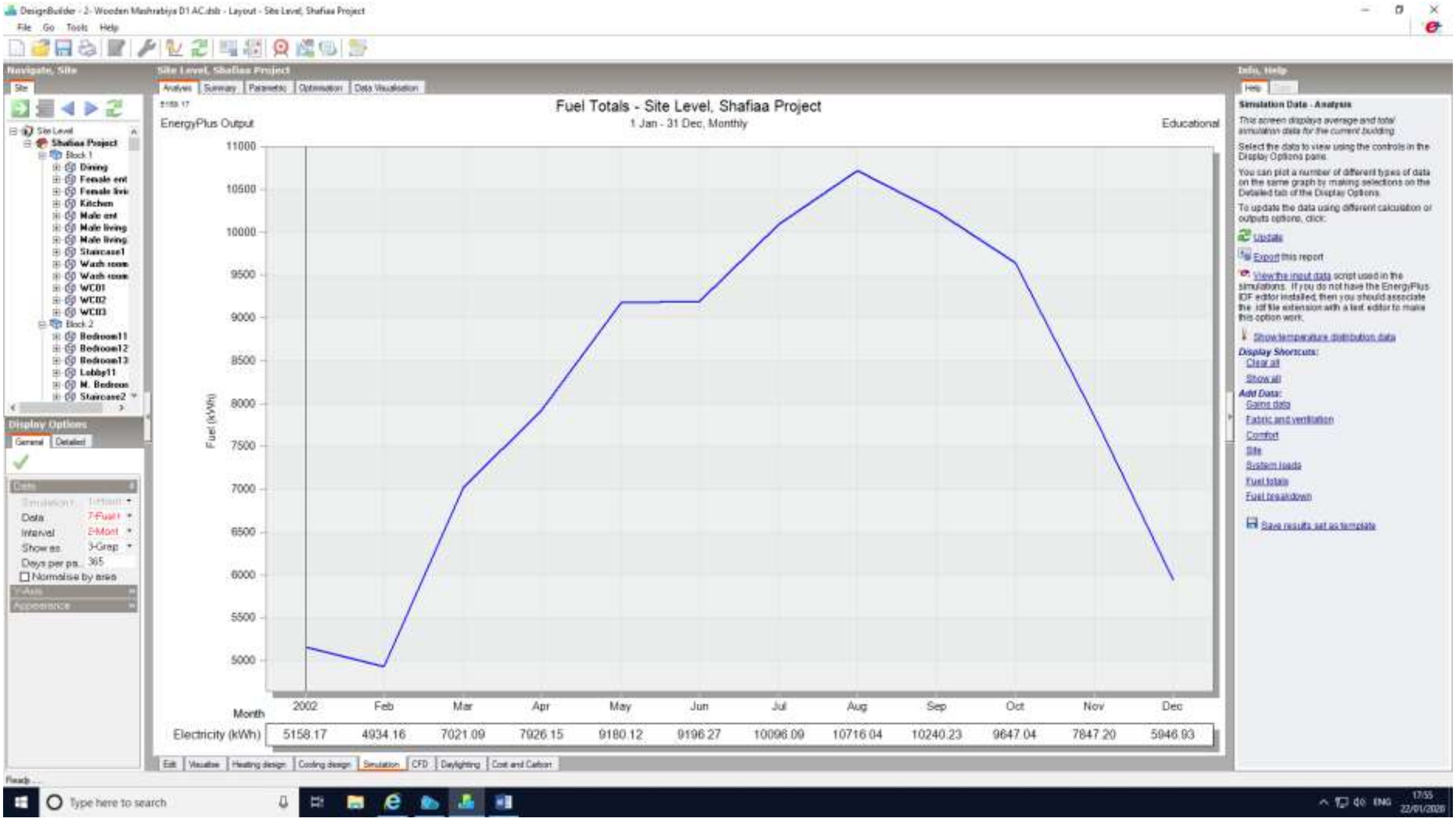


DesignBuilder - 2- Wooden Mashrabiya D1 AC.dsb - Layout - Site Level, Shafiaa Project
Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
General Lighting (kWh)
Computer + Equip (kWh)
Occupancy (kWh)
Solar Gains Exterior Windows (kWh)
Zone Sensible Heating (kWh)
Zone Sensible Cooling (kWh)
Heat Balance (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
General Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
Computer + Equip (kWh) 43.55 39.16 42.20 43.88 42.20 41.19 44.90 42.20 42.54 43.55 41.19 44.90
Occupancy (kWh) 126.15 111.66 136.77 132.01 134.69 130.10 134.30 131.32 128.52 135.10 131.71 121.24
Solar Gains Exterior Windows (kWh) 61.65 67.25 81.59 87.36 90.59 87.26 86.86 82.97 79.83 79.03 70.00 62.05
Zone Sensible Heating (kWh) 0.00 0.00 1.35 0.08 0.05 0.04 0.04 0.69 0.26 0.04 0.15 0.60
Zone Sensible Cooling (kWh) -3081.27 -3363.76 -7508.27 -9257.28 -11517.07 -11623.30 -13392.18 -13107.84 -11744.63 -10959.96 -8276.52 -4256.27

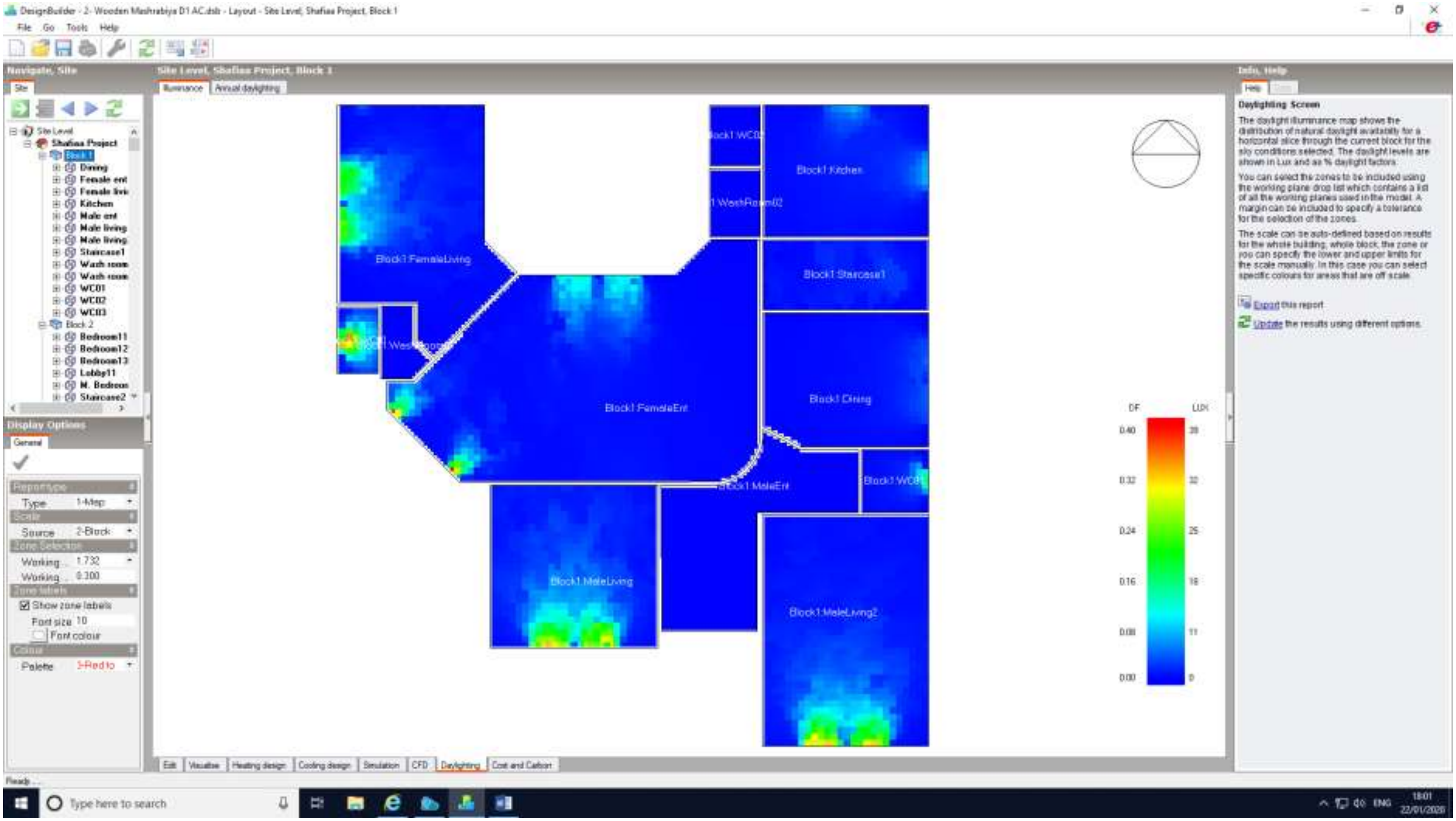

Fuel Breakdown - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Fuel (kWh)
Year
Room Electricity (kWh) 511.45
Lighting (kWh) 51308.96
Cooling (Electricity) (kWh) 43252.77
DHW (Electricity) (kWh) 2836.28

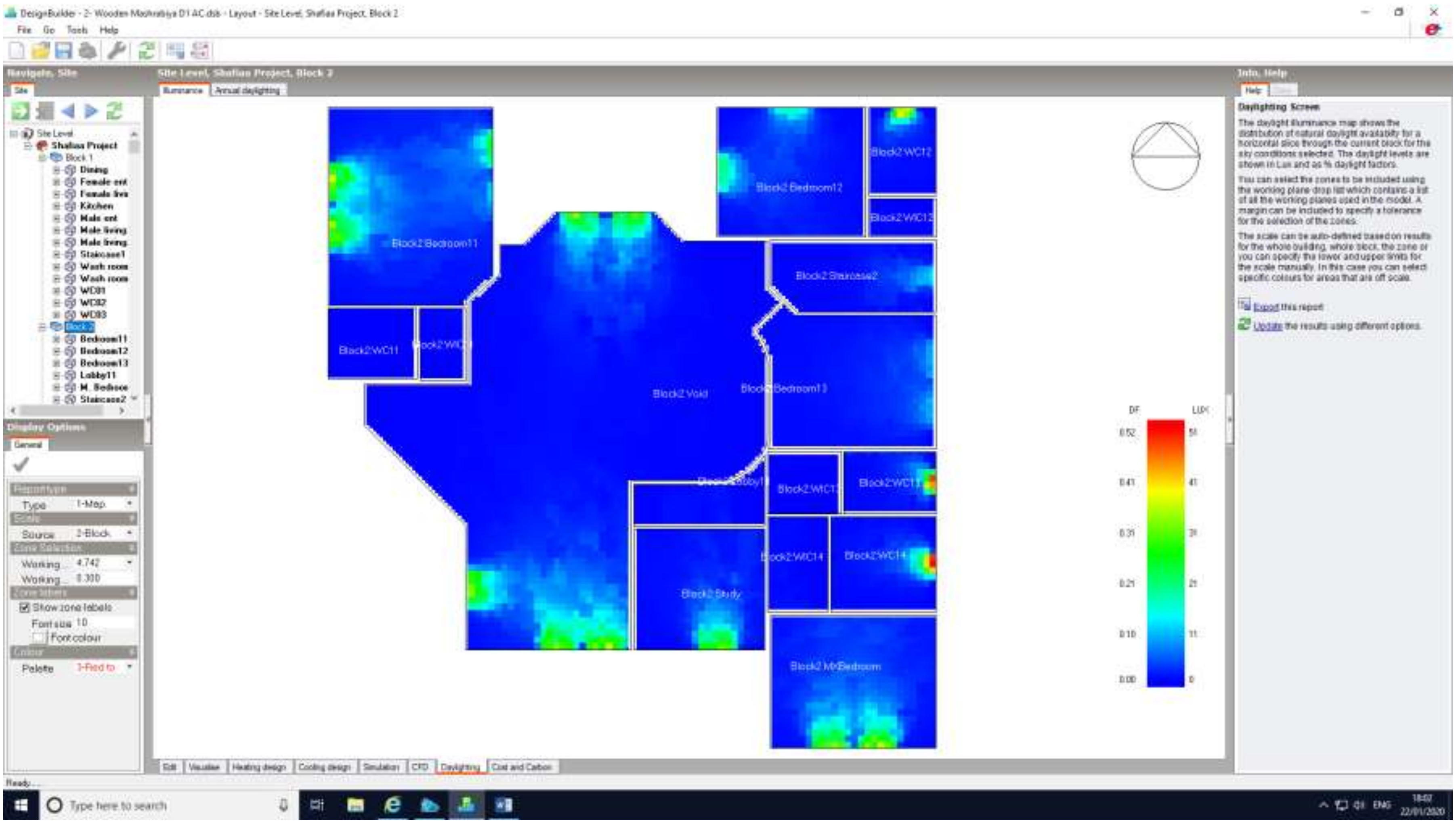

Fuel Breakdown - Site Level, Shafiaa Project
1 Jan - 31 Dec, Monthly
EnergyPlus Output
Educational
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Room Electricity (kWh) 43.55 39.16 42.20 43.88 42.20 41.19 44.90 42.20 42.54 43.55 41.19 44.90
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
Cooling (Electricity) (kWh) 515.42 741.77 2386.60 3422.49 4545.63 4709.15 5445.07 6081.54 5744.84 5004.28 3360.07 1295.91
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89

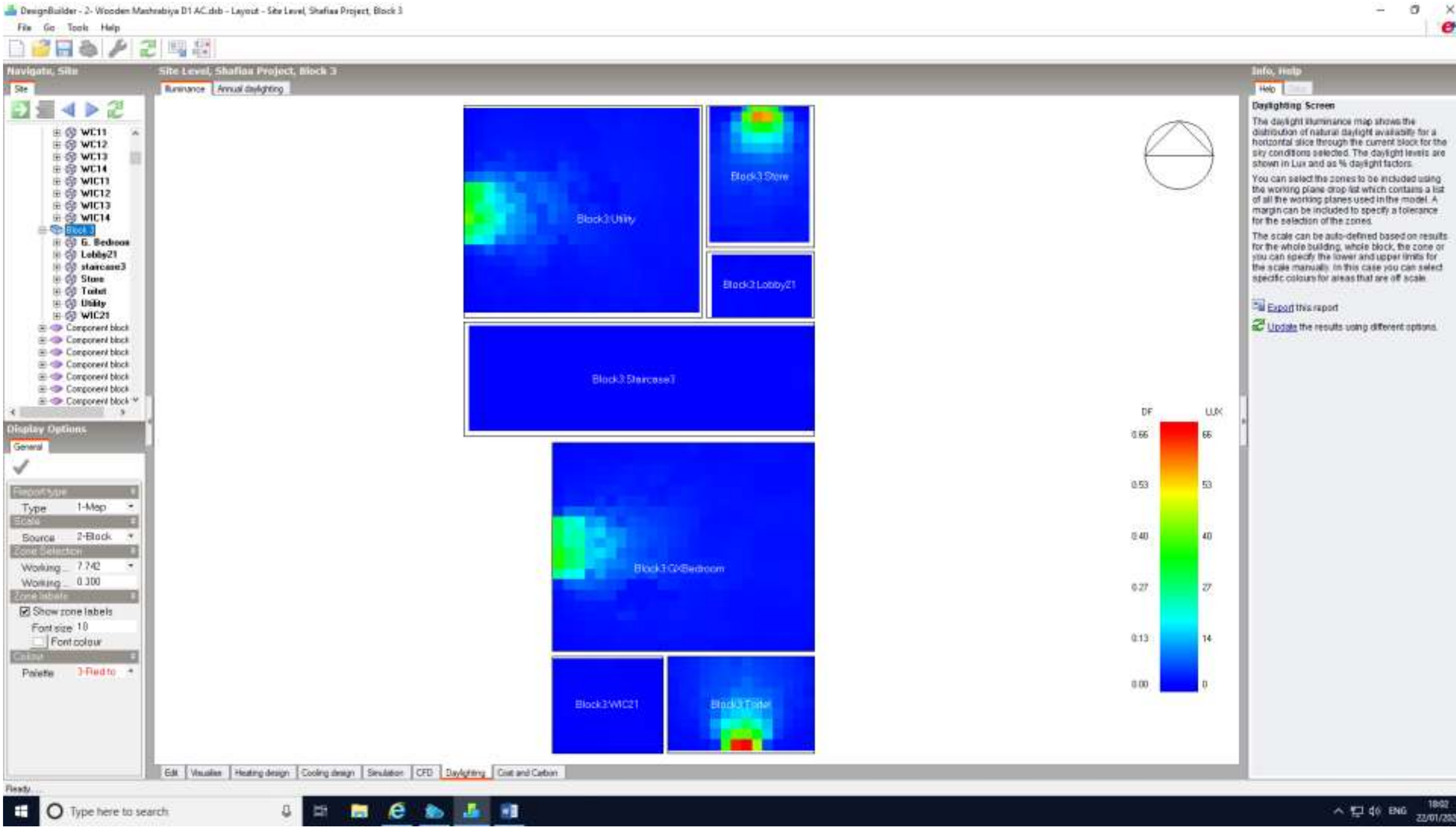

Fuel Totals - Site Level, Shafiaa Project
1 Jan - 31 Dec, Annual
EnergyPlus Output
Educational
Fuel (MWh)
Year
Electricity (MWh)
97.91



Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Electricity (kWh) 5158.17 4934.16 7021.09 7926.15 9180.12 9196.27 10096.09 10716.04 10240.23 9647.04 7847.20 5946.93

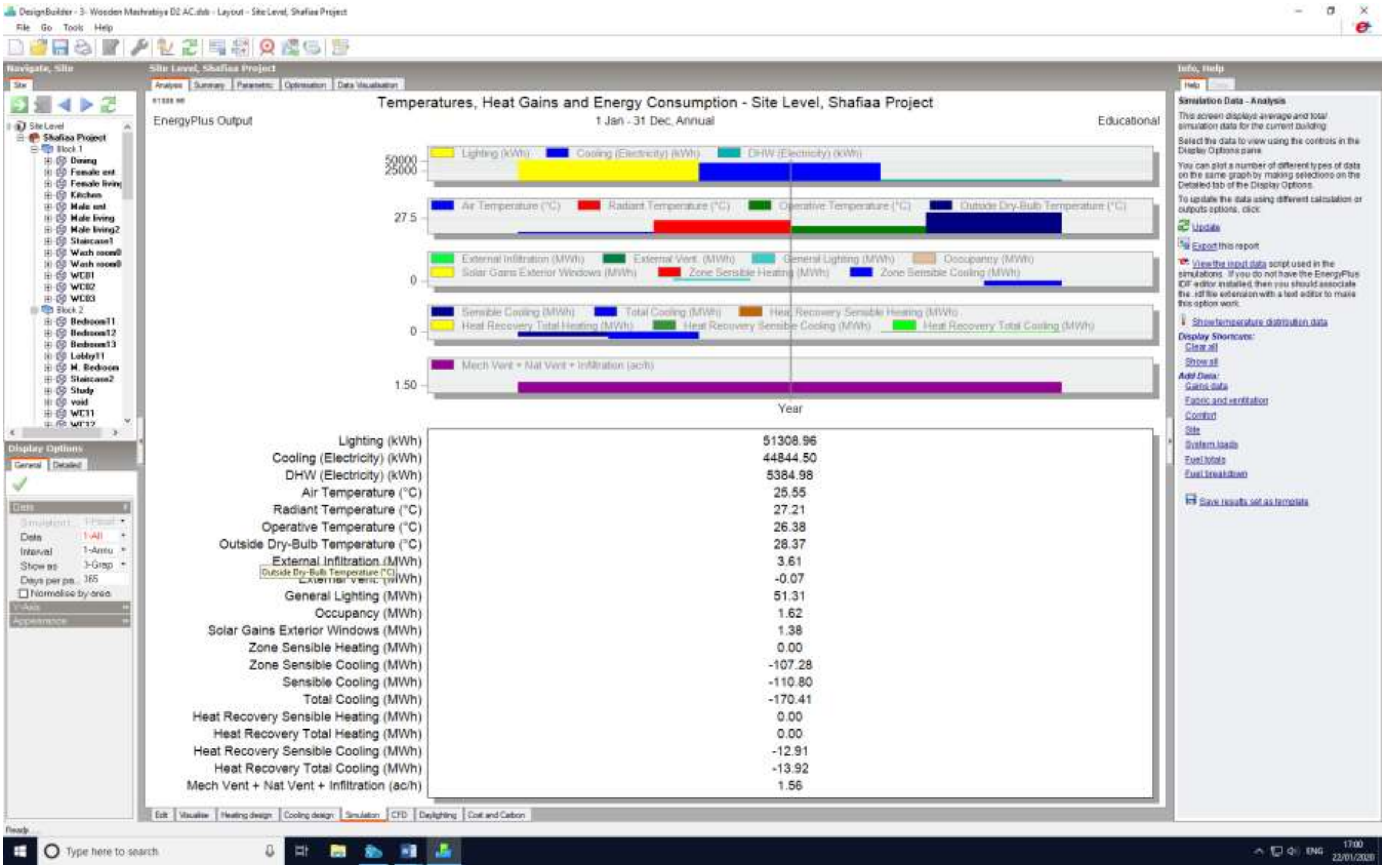


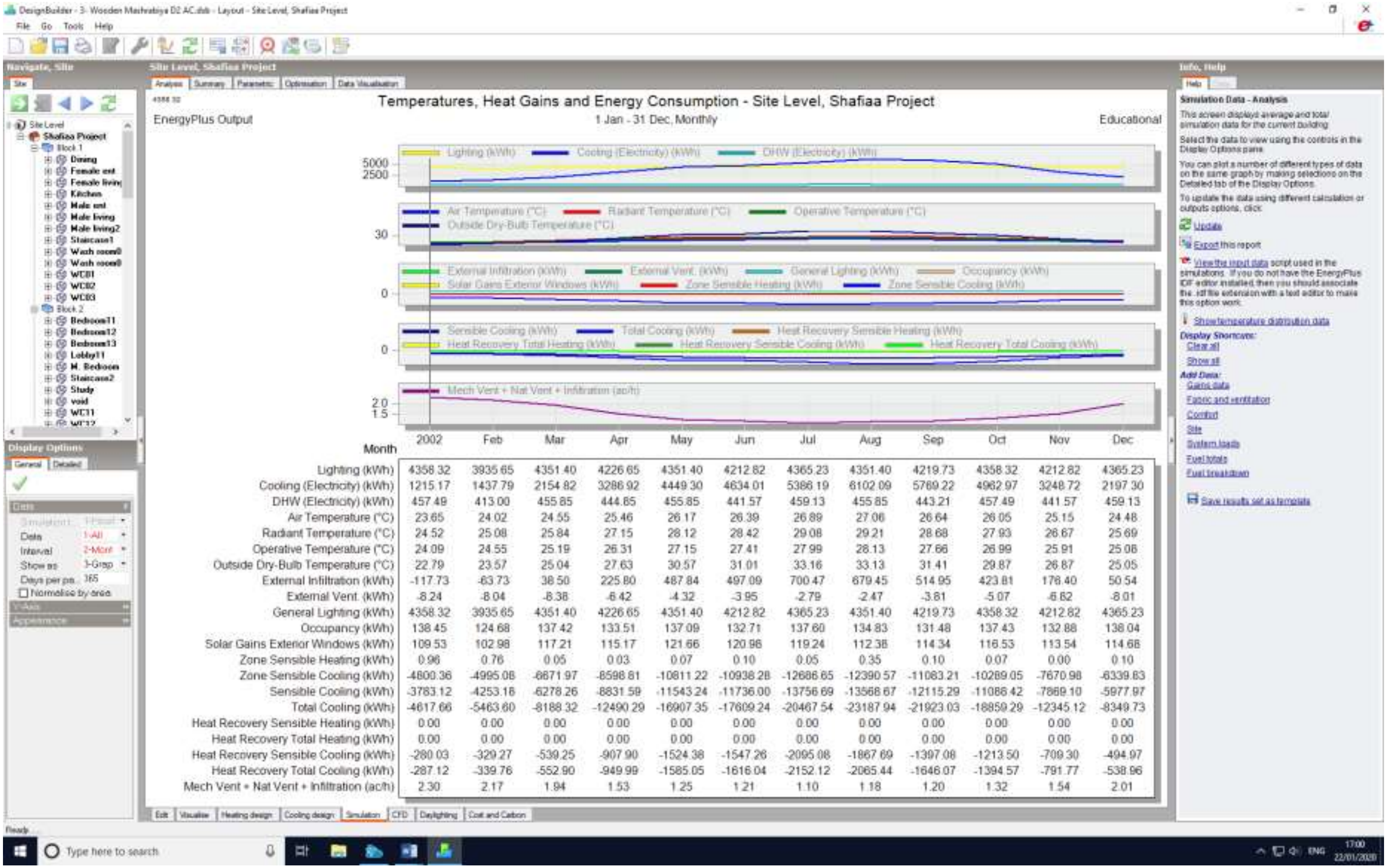




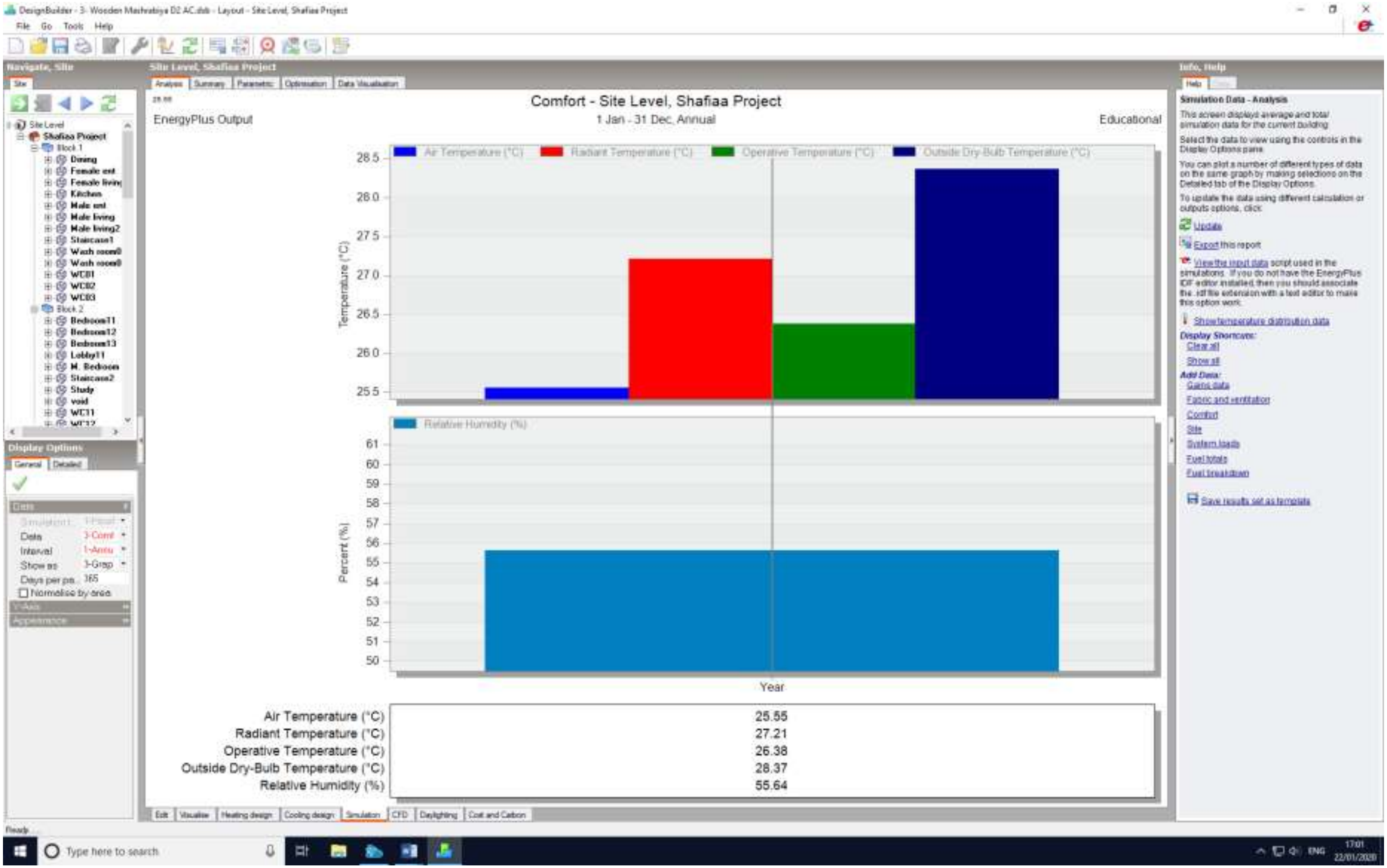
DesignBuilder - 2- Wooden Mashrabiya D1 AC.dsb - Layout - Site Level, Shafiaa Project, Block 3
File Go Tools Help
Navigate, Site
Site Level, Shafiaa Project, Block 3
Illuminance
Annual daylighting
Info, Help
Daylighting Screen
Block3:Utility
Block3:Store
Block3:Lobby21
Block3:Staircase3
Block3:G.Bedroom
Block3:WIC21
Block3:Toilet
DF
LUX
0.66
0.53
0.40
0.27
0.13
0.00
66
53
40
27
14
0
Display Options
Edit
Visualise
Heating design
Cooling design
Simulation
CFD
Daylighting
Cost and Carbon
Type here to search

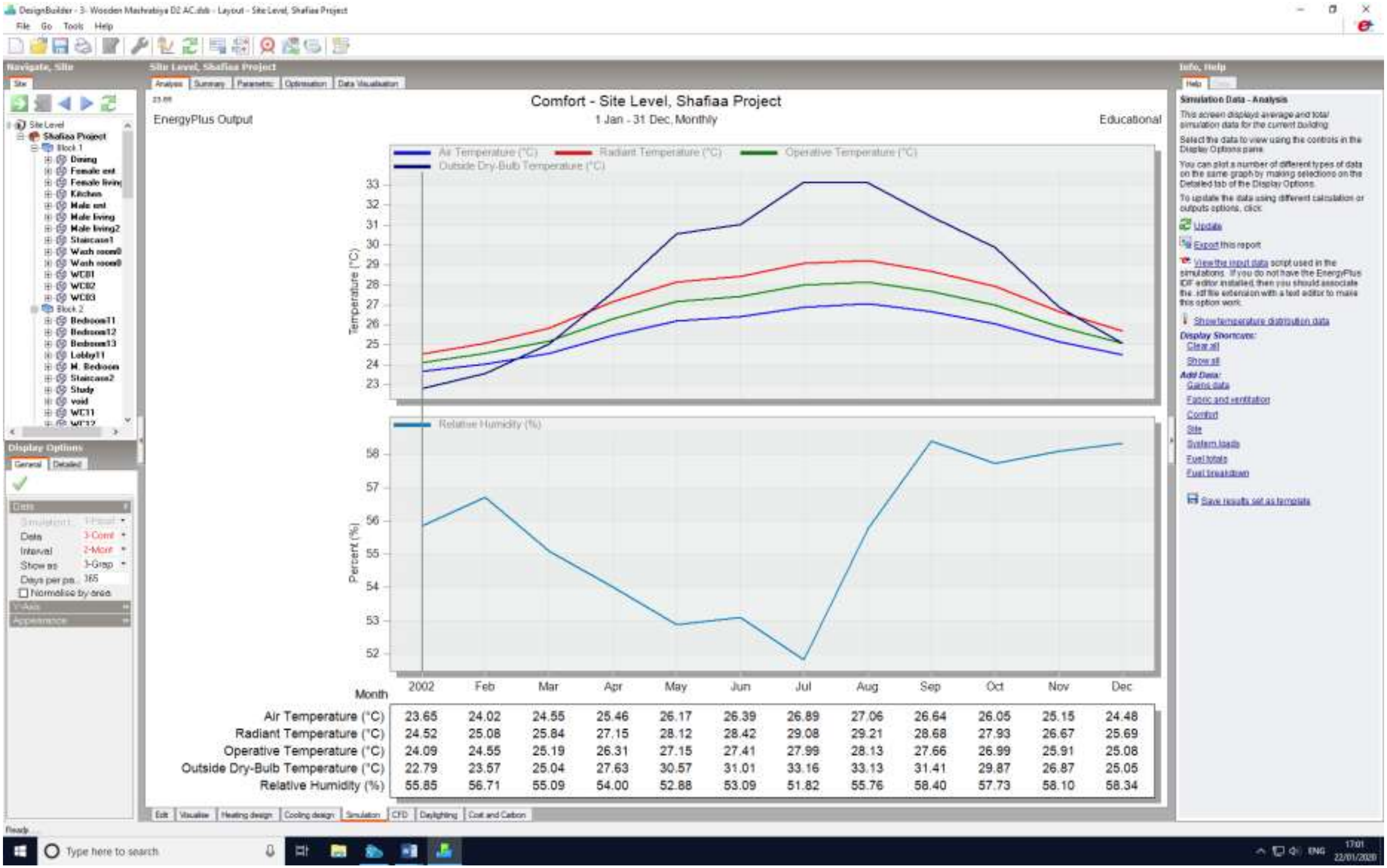
8- Wooden mashrabiya D2 with AC

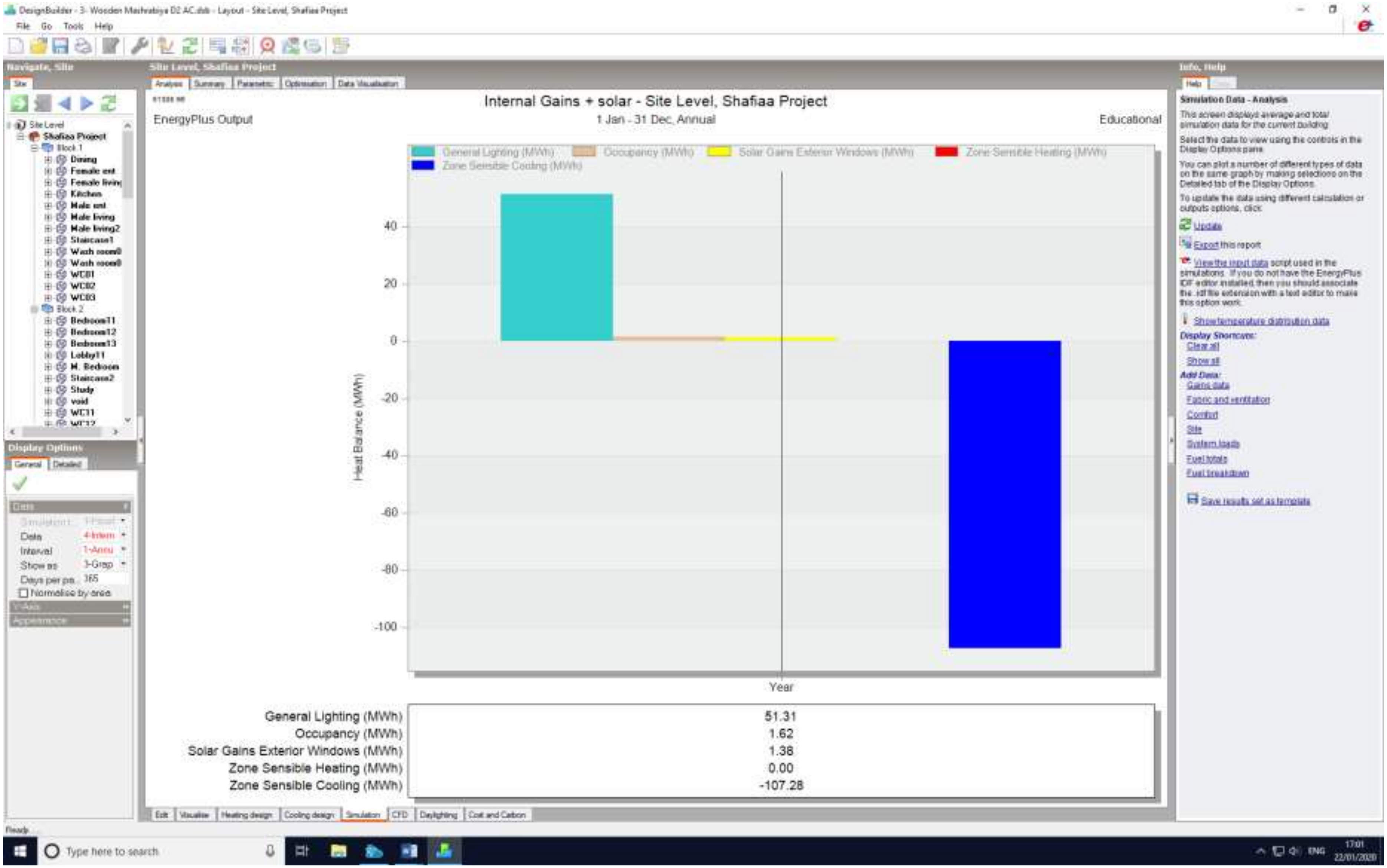


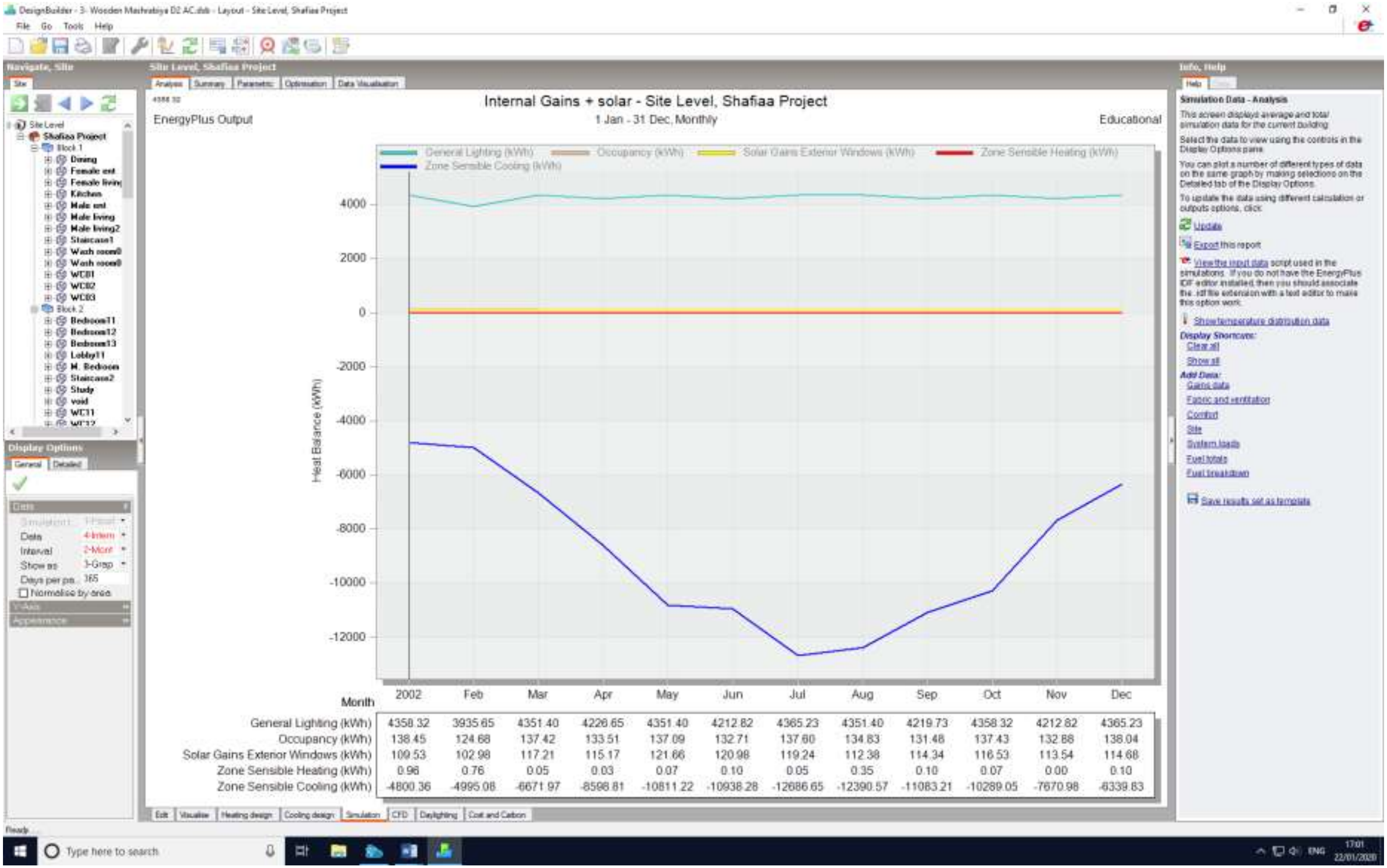


Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Cooling (Electricity) (kWh)	1215.17	1437.79	2154.82	3286.92	4449.30	4634.01	5386.19	6102.09	5769.22	4962.97	3248.72	2197.30
DHW (Electricity) (kWh)	457.49	413.00	455.85	444.85	455.85	441.57	459.13	455.85	443.21	457.49	441.57	459.13
Air Temperature (°C)	23.65	24.02	24.55	25.46	26.17	26.39	26.89	27.06	26.64	26.05	25.15	24.48
Radiant Temperature (°C)	24.52	25.08	25.84	27.15	28.12	28.42	29.08	29.21	28.68	27.93	26.67	25.69
Operative Temperature (°C)	24.09	24.55	25.19	26.31	27.15	27.41	27.99	28.13	27.66	26.99	25.91	25.08
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-117.73	-63.73	38.50	225.80	487.84	497.09	700.47	679.45	514.95	423.81	176.40	50.54
External Vent. (kWh)	-8.24	-8.04	-8.38	-6.42	-4.32	-3.95	-2.79	-2.47	-3.81	-5.07	-6.82	-8.01
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Occupancy (kWh)	138.45	124.68	137.42	133.51	137.09	132.71	137.60	134.83	131.48	137.43	132.88	138.04
Solar Gains Exterior Windows (kWh)	109.53	102.98	117.21	115.17	121.66	120.96	119.24	112.38	114.34	116.53	113.54	114.68
Zone Sensible Heating (kWh)	0.96	0.76	0.05	0.03	0.07	0.10	0.05	0.35	0.10	0.07	0.00	0.10
Zone Sensible Cooling (kWh)	-4800.36	-4995.08	-6671.97	-8598.81	-10811.22	-10938.28	-12686.65	-12390.57	-11083.21	-10289.05	-7670.98	-6339.83
Sensible Cooling (kWh)	-3783.12	-4253.16	-6278.26	-8831.59	-11543.24	-11736.00	-13756.69	-13568.67	-12115.29	-11086.42	-7869.10	-5977.97
Total Cooling (kWh)	-4617.66	-5463.60	-8188.32	-12490.29	-16907.35	-17609.24	-20467.54	-23187.94	-21923.03	-18859.29	-12345.12	-8349.73
Heat Recovery Sensible Heating (kWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery Total Heating (kWh)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery Sensible Cooling (kWh)	-280.03	-329.27	-539.25	-907.90	-1524.38	-1547.26	-2095.08	-1867.69	-1397.08	-1213.50	-709.30	-494.97
Heat Recovery Total Cooling (kWh)	-287.12	-339.76	-552.90	-949.99	-1585.05	-1616.04	-2152.12	-2065.44	-1646.07	-1394.57	-791.77	-538.96
Mech Vent + Nat Vent + Infiltration (ac/h)	2.30	2.17	1.94	1.53	1.25	1.21	1.10	1.18	1.20	1.32	1.54	2.01

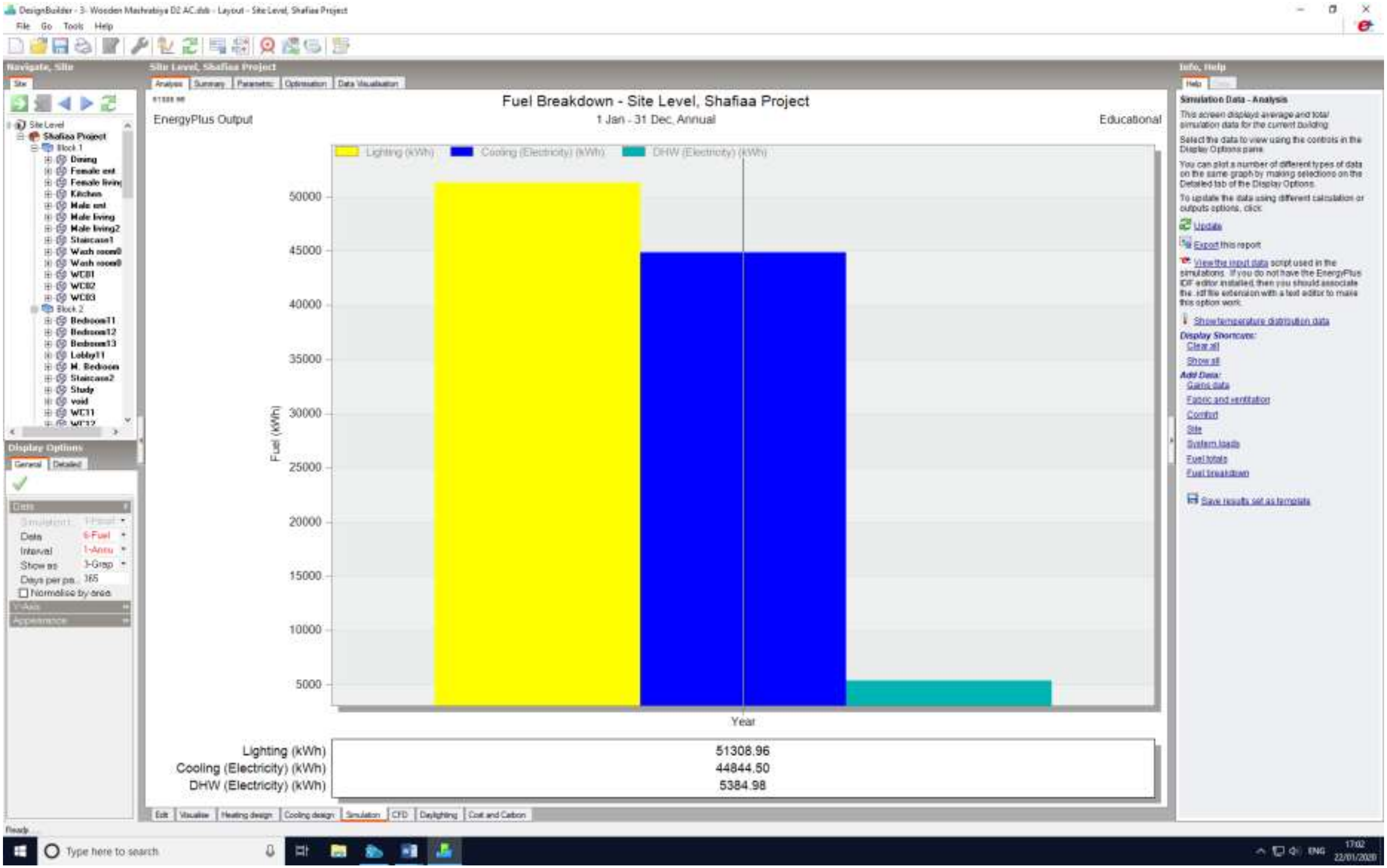

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Year
Air Temperature (°C) 25.55
Radiant Temperature (°C) 27.21
Operative Temperature (°C) 26.38
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 55.64

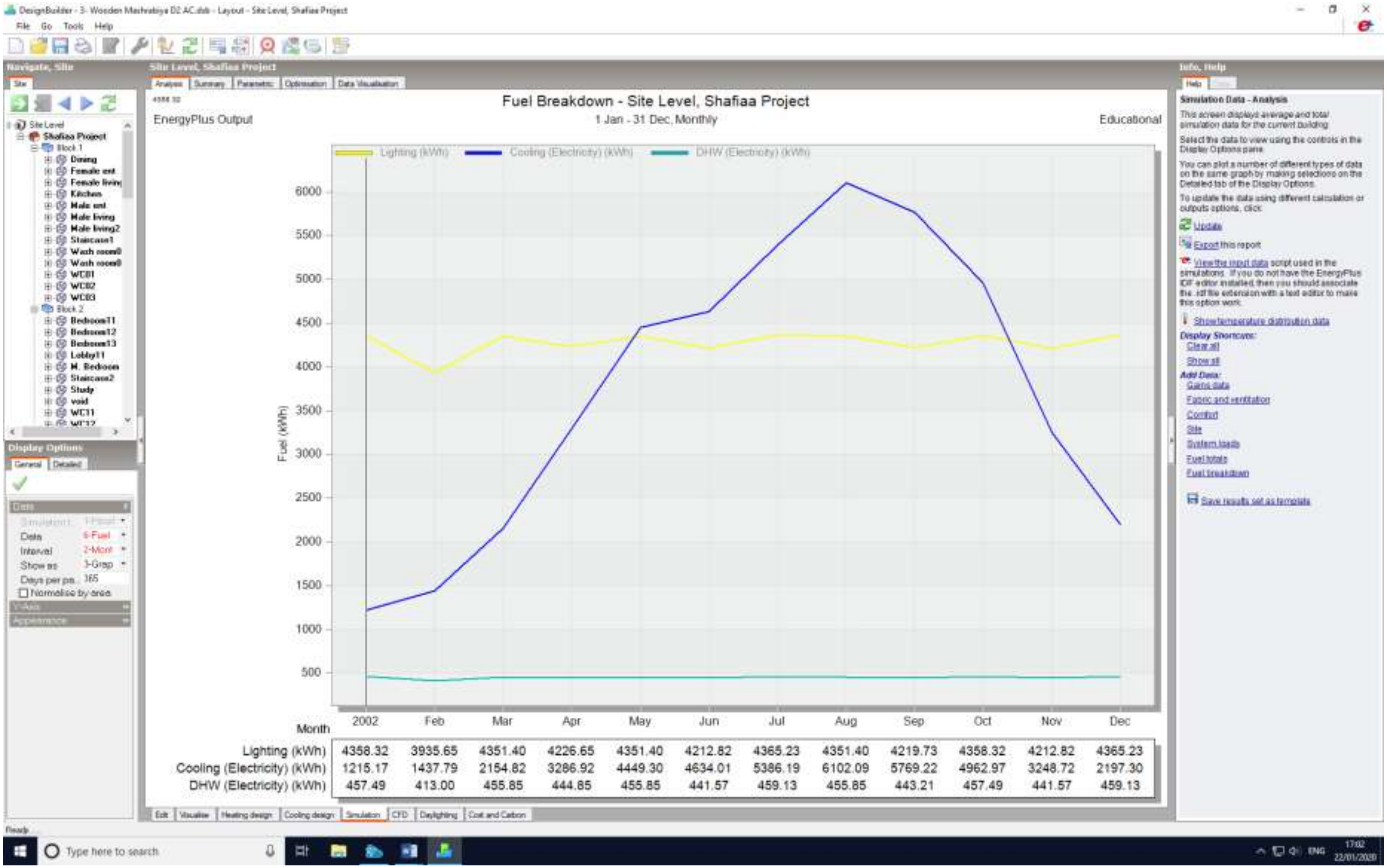

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Air Temperature (°C) 23.65 24.02 24.55 25.46 26.17 26.39 26.89 27.06 26.64 26.05 25.15 24.48
Radiant Temperature (°C) 24.52 25.08 25.84 27.15 28.12 28.42 29.08 29.21 28.68 27.93 26.67 25.69
Operative Temperature (°C) 24.09 24.55 25.19 26.31 27.15 27.41 27.99 28.13 27.66 26.99 25.91 25.08
Outside Dry-Bulb Temperature (°C) 22.79 23.57 25.04 27.63 30.57 31.01 33.16 33.13 31.41 29.87 26.87 25.05
Relative Humidity (%) 55.85 56.71 55.09 54.00 52.88 53.09 51.82 55.76 58.40 57.73 58.10 58.34

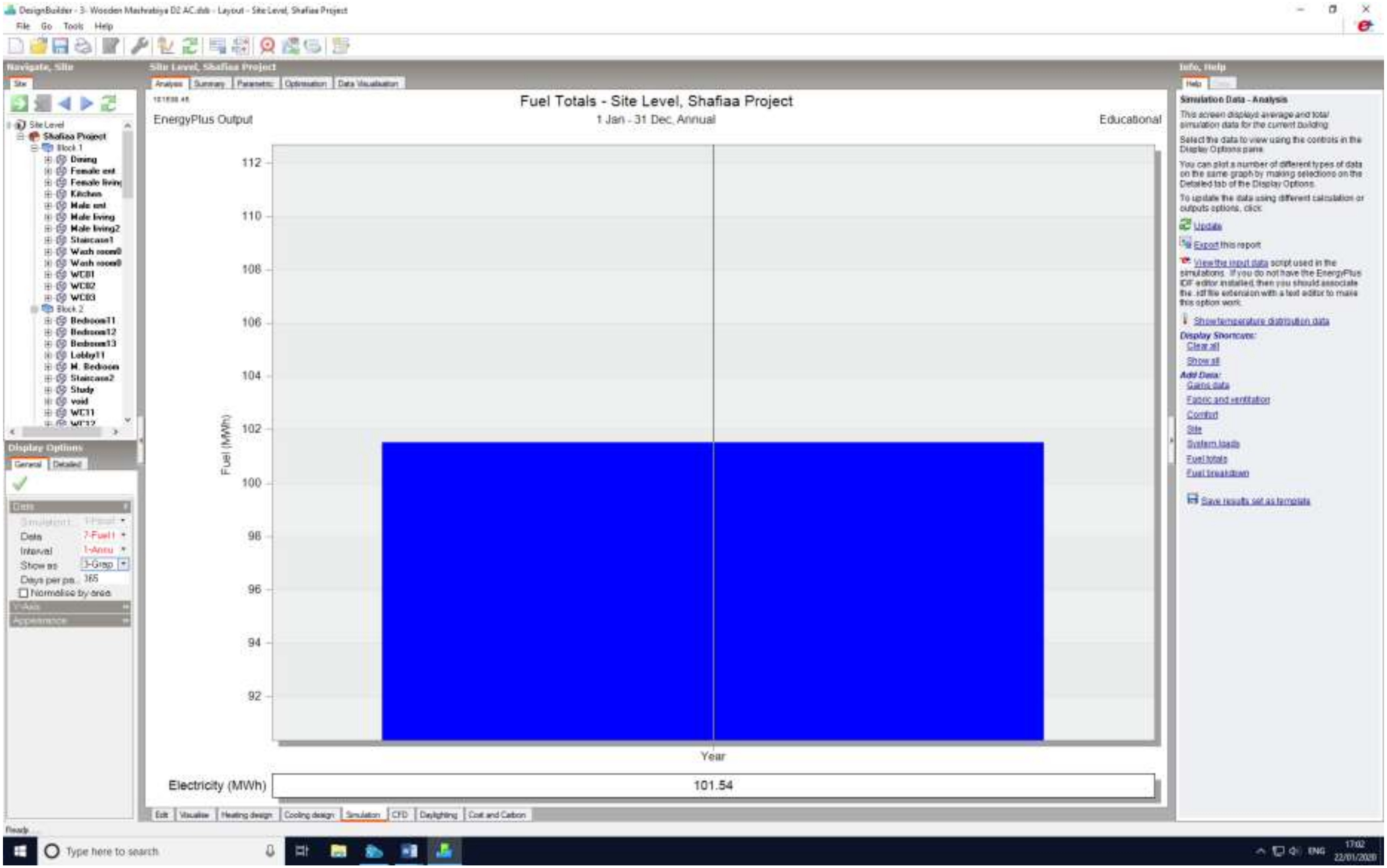

Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
General Lighting (MWh)
Occupancy (MWh)
Solar Gains Exterior Windows (MWh)
Zone Sensible Heating (MWh)
Zone Sensible Cooling (MWh)
Heat Balance (MWh)
Year
General Lighting (MWh) 51.31
Occupancy (MWh) 1.62
Solar Gains Exterior Windows (MWh) 1.38
Zone Sensible Heating (MWh) 0.00
Zone Sensible Cooling (MWh) -107.28

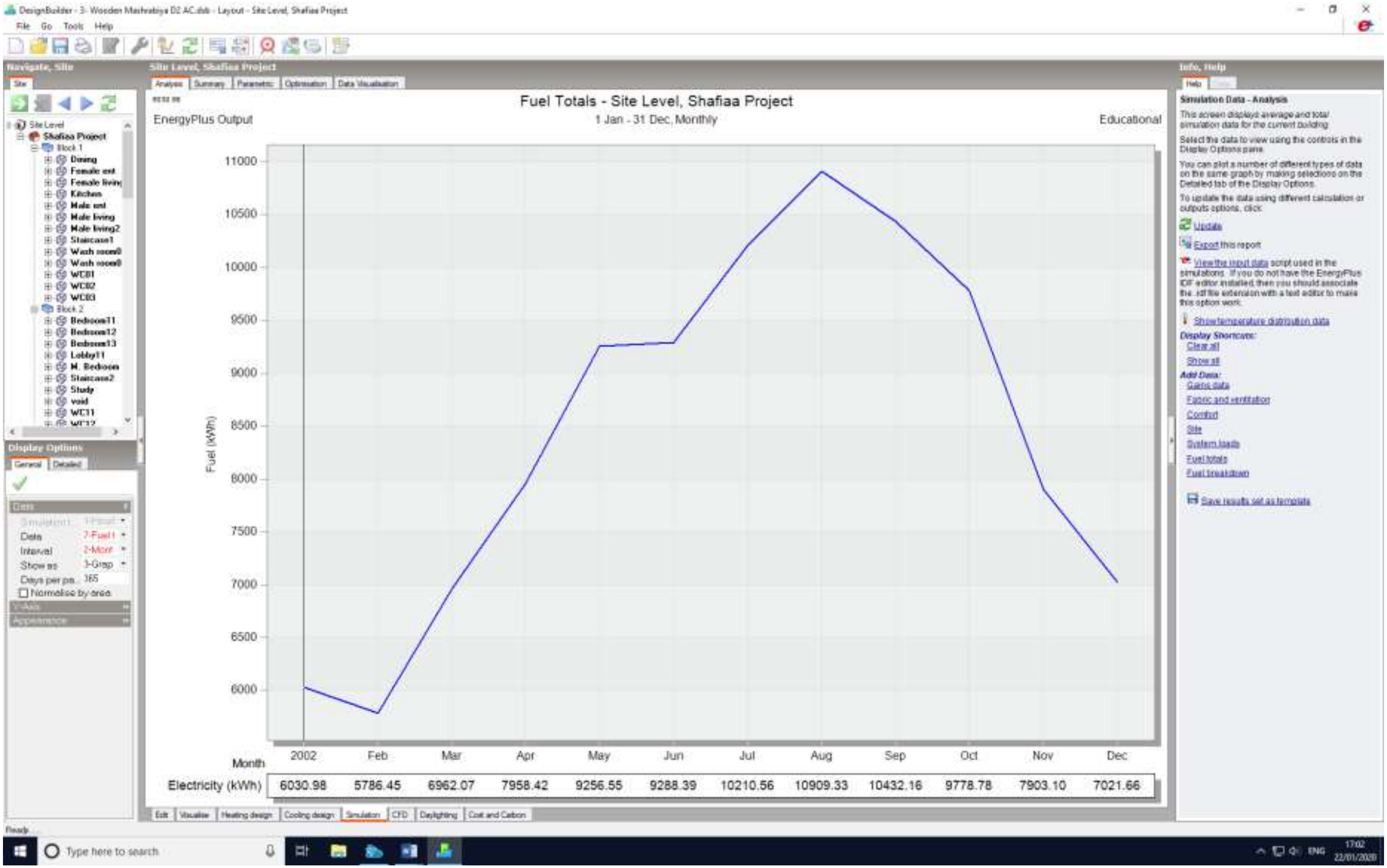


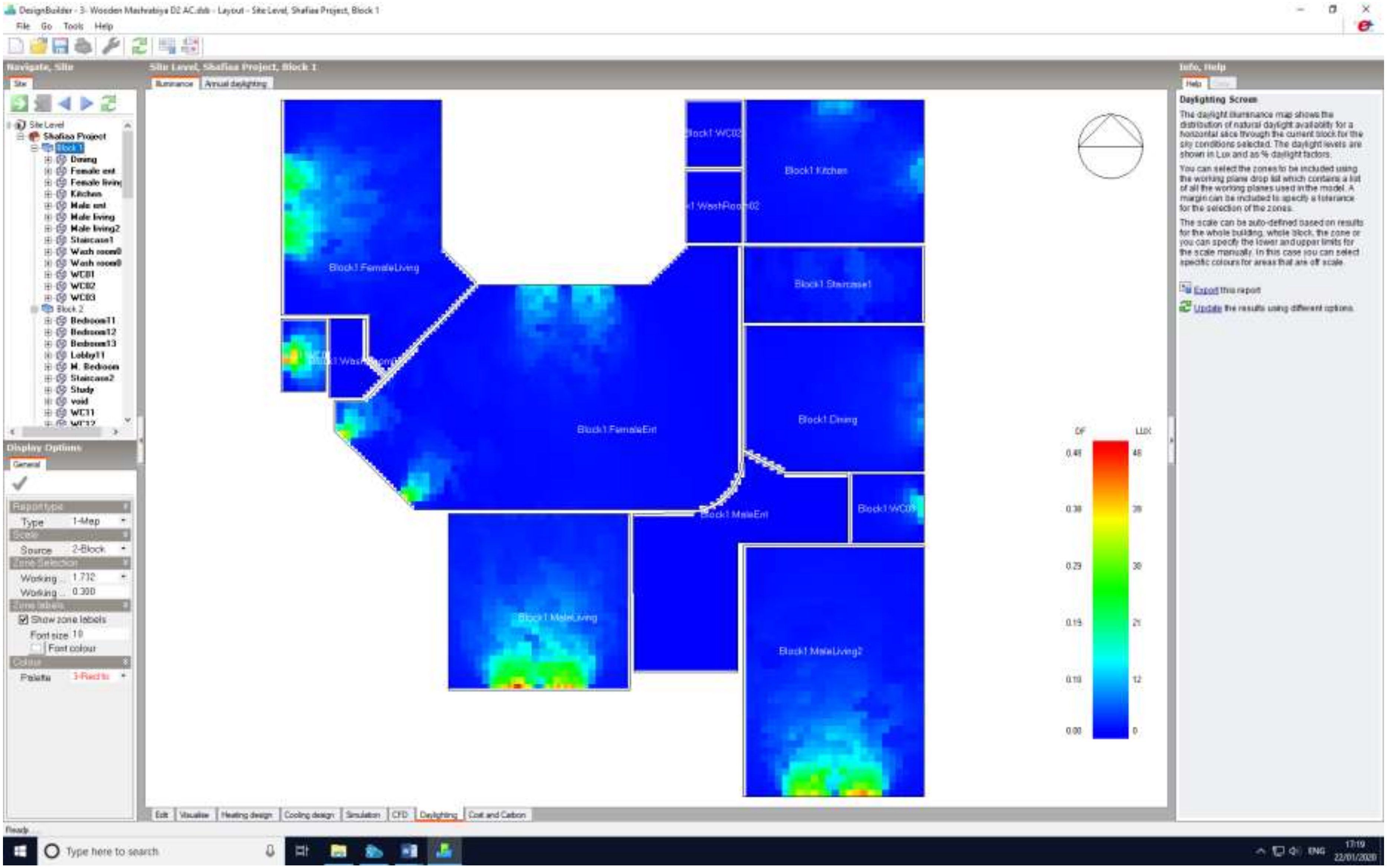
Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
General Lighting (kWh)
Occupancy (kWh)
Solar Gains Exterior Windows (kWh)
Zone Sensible Heating (kWh)
Zone Sensible Cooling (kWh)
Heat Balance (kWh)
Month
Month 2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
General Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
Occupancy (kWh) 138.45 124.68 137.42 133.51 137.09 132.71 137.60 134.83 131.48 137.43 132.88 138.04
Solar Gains Exterior Windows (kWh) 109.53 102.98 117.21 115.17 121.66 120.98 119.24 112.38 114.34 116.53 113.54 114.68
Zone Sensible Heating (kWh) 0.96 0.76 0.05 0.03 0.07 0.10 0.05 0.35 0.10 0.07 0.00 0.10
Zone Sensible Cooling (kWh) -4800.36 -4995.08 -6671.97 -8598.81 -10811.22 -10938.28 -12686.65 -12390.57 -11083.21 -10289.05 -7670.98 -6339.83


Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Year
Lighting (kWh) 51308.96
Cooling (Electricity) (kWh) 44844.50
DHW (Electricity) (kWh) 5384.98

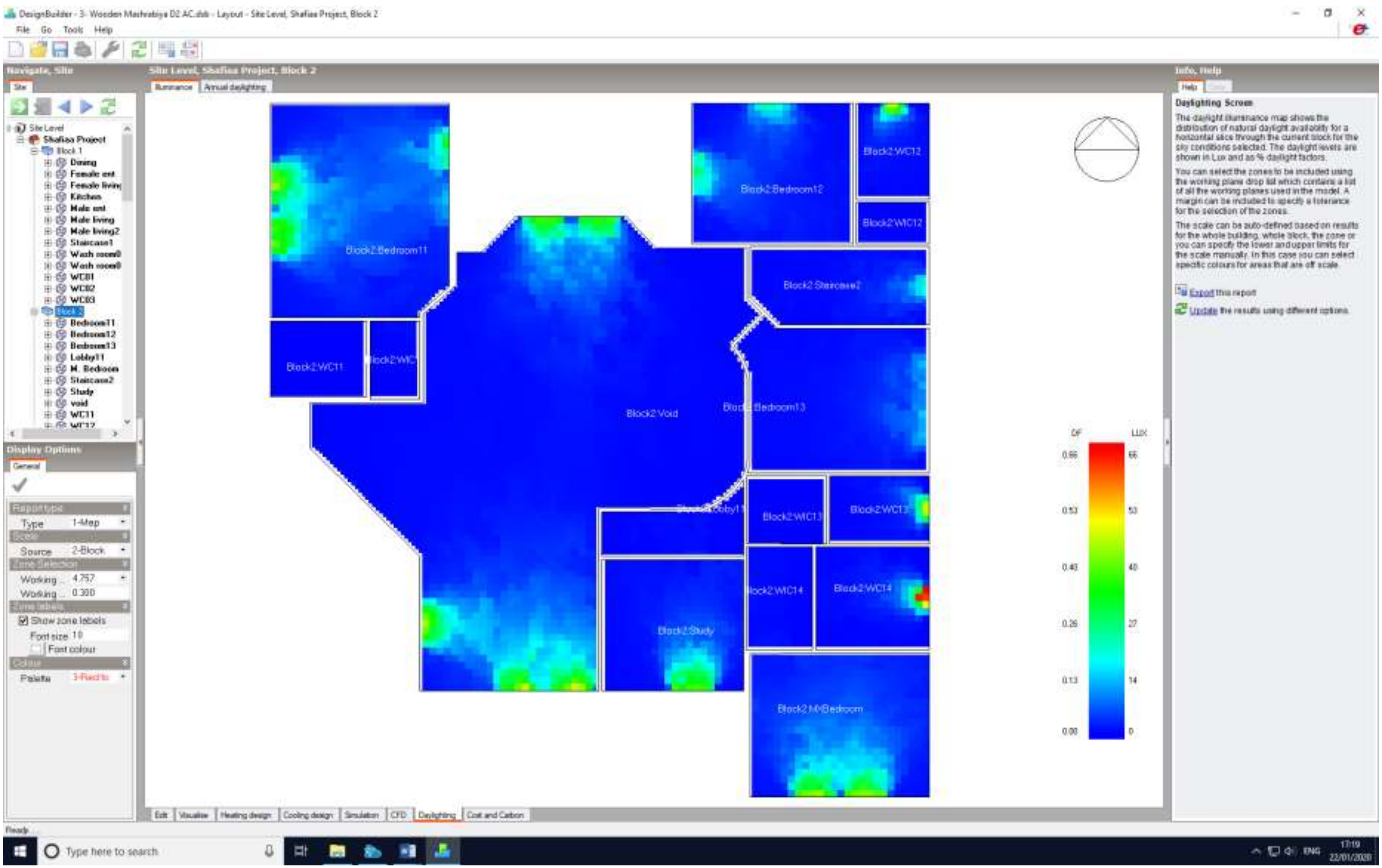

Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
Cooling (Electricity) (kWh) 1215.17 1437.79 2154.82 3286.92 4449.30 4634.01 5386.19 6102.09 5769.22 4962.97 3248.72 2197.30
DHW (Electricity) (kWh) 457.49 413.00 455.85 444.85 455.85 441.57 459.13 455.85 443.21 457.49 441.57 459.13

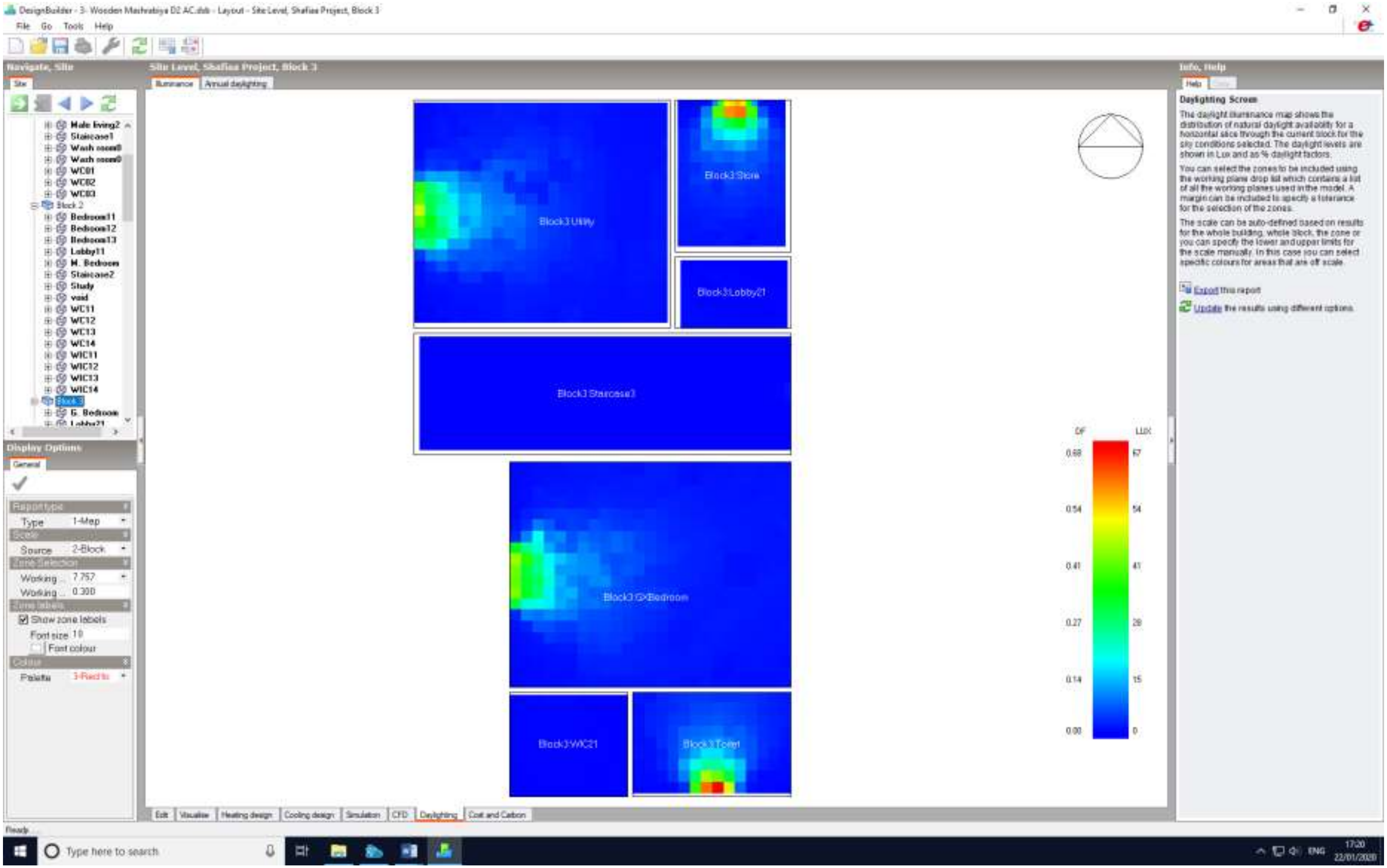

Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Fuel (MWh)
Year
Electricity (MWh)
101.54


Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
Month
Electricity (kWh)
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
6030.98 5786.45 6962.07 7958.42 9256.55 9288.39 10210.56 10909.33 10432.16 9778.78 7903.10 7021.66



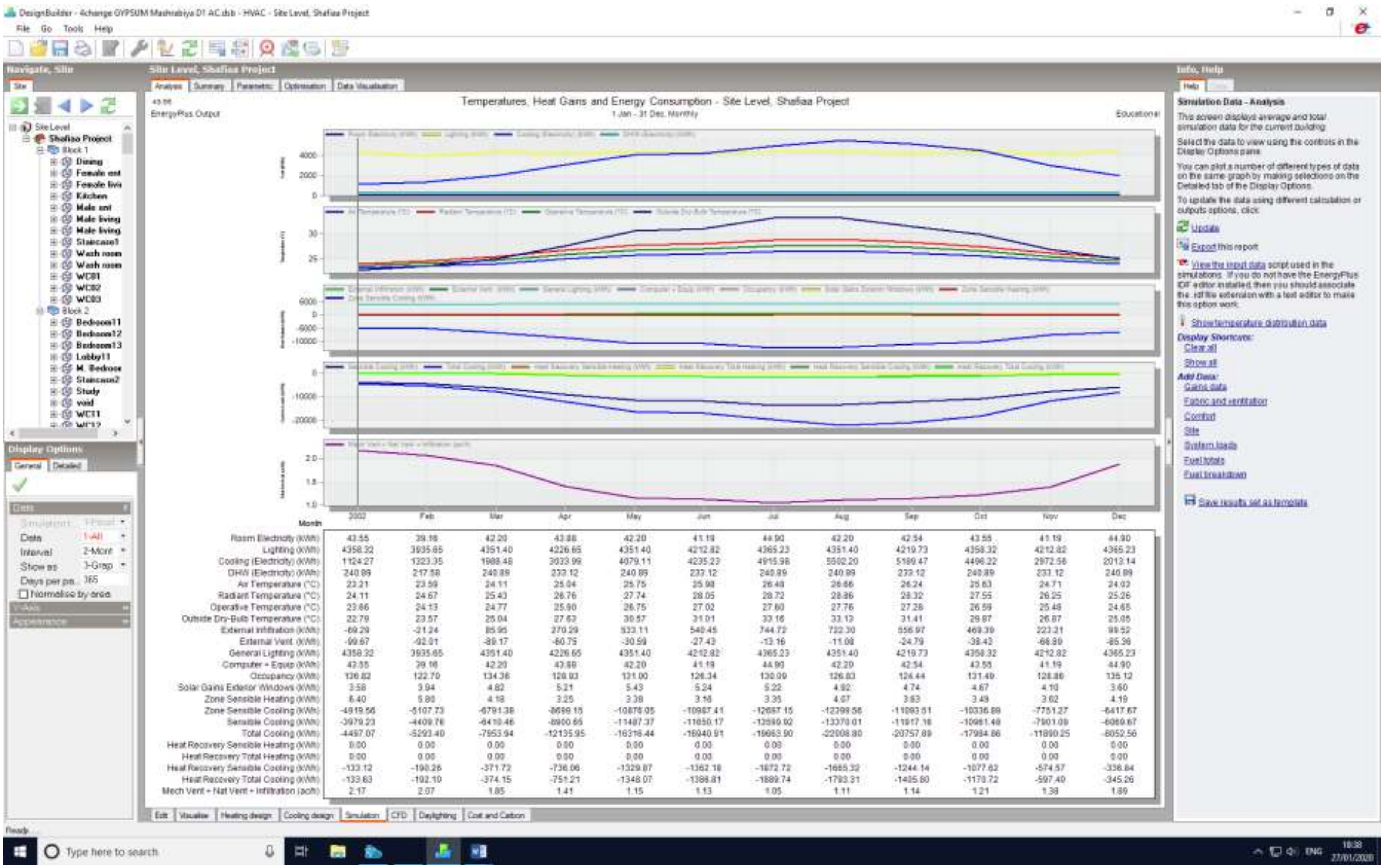
Block1 FemaleLiving
Block1 WC02
Block1 Kitchen
Block1 Staircase1
Block1 FemaleEnt
Block1 Dining
Block1 MaleEnt
Block1 MaleLiving
Block1 MaleLiving2
DF
LUX
Daylighting Screen
Ready
Type here to search

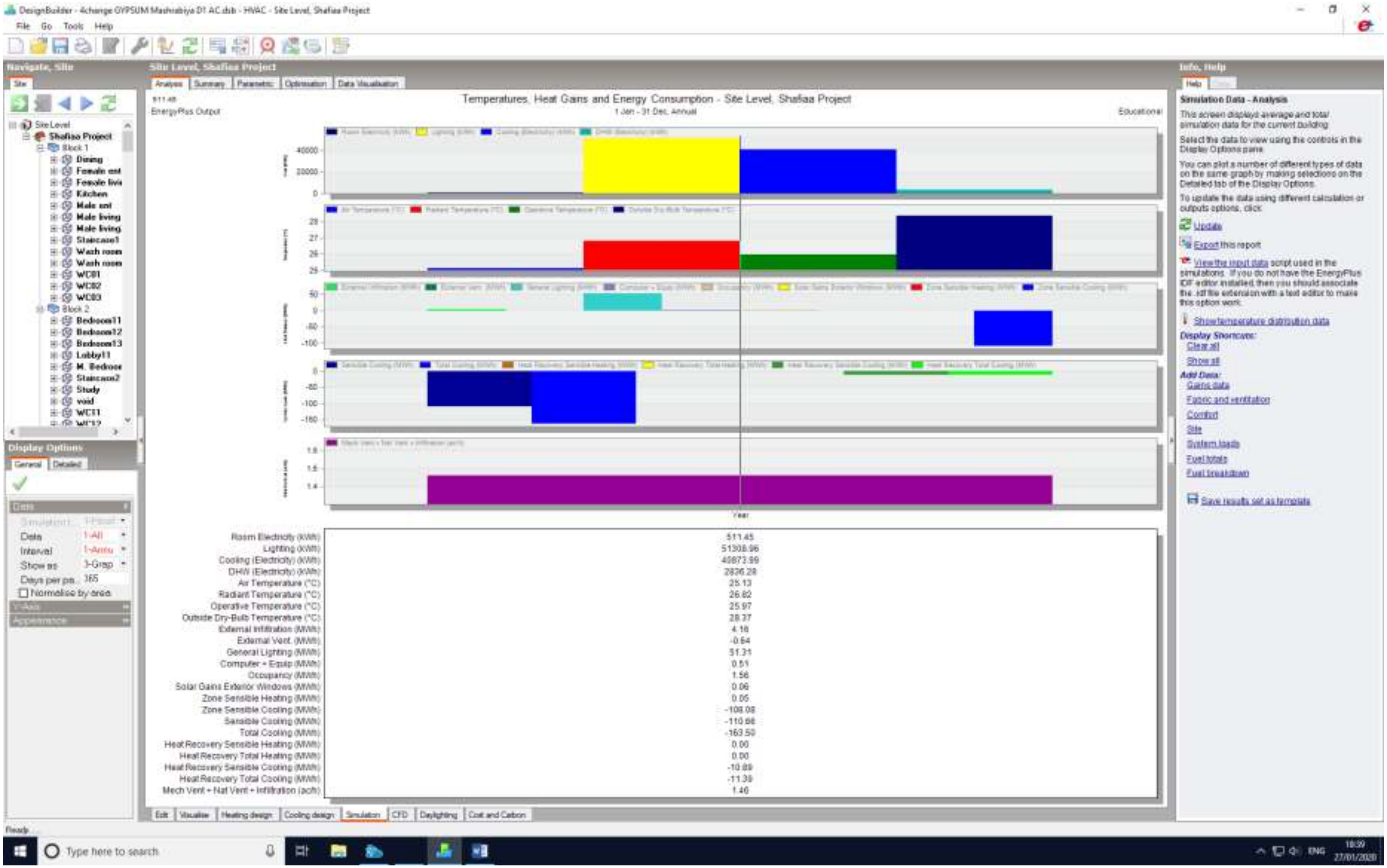

Site Level, Shafiaa Project, Block 2
Block2:Bedroom11
Block2:Bedroom12
Block2:WC12
Block2:WC12
Block2:Staircase2
Block2:WC11
Block2:Void
Block2:Bedroom13
Block2:WC13
Block2:WC13
Block2:WC14
Block2:WC14
Block2:Study
Block2:M.Bedroom
Daylighting Screen

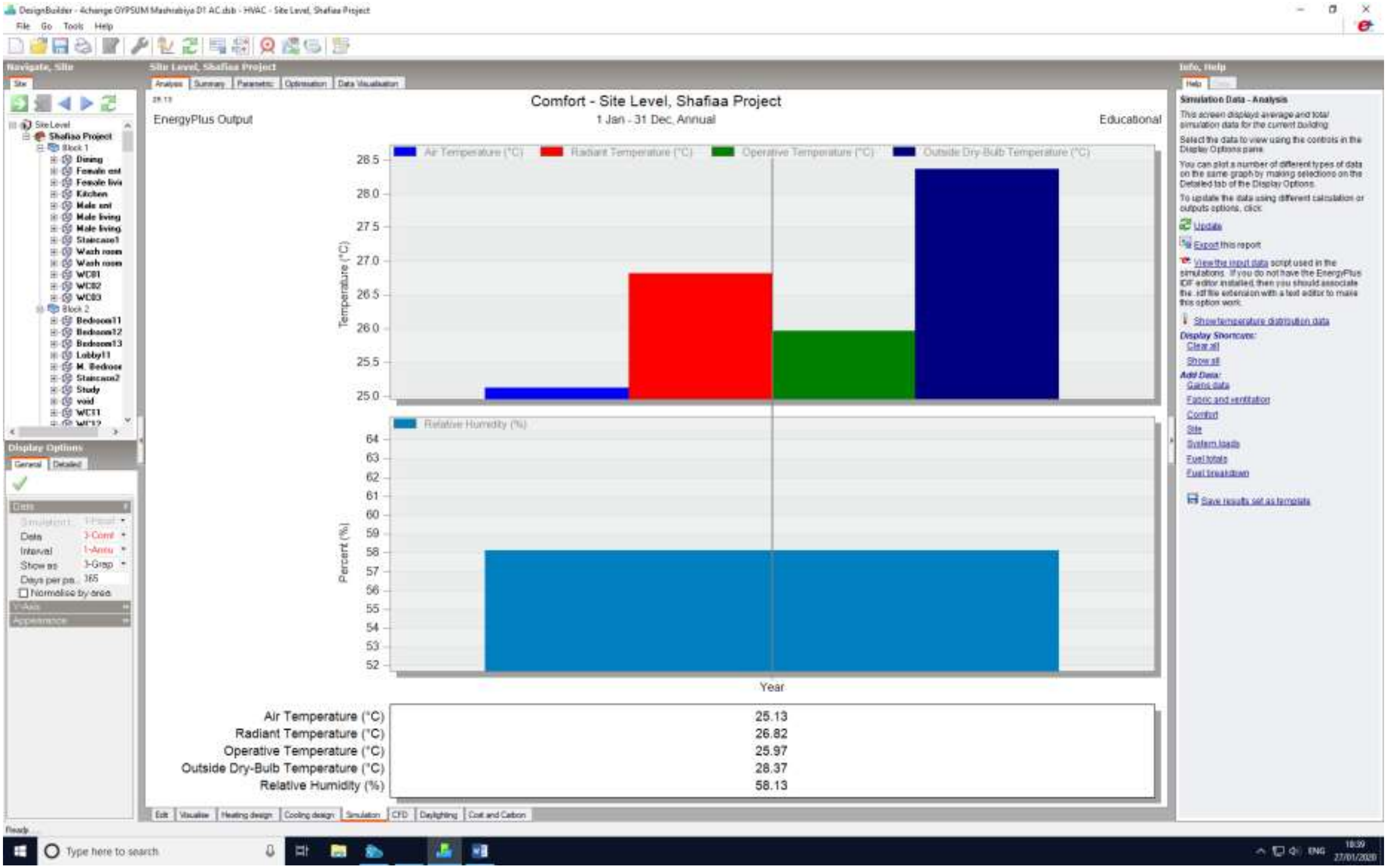


Block3:Utility
Block3:Store
Block3:Lobby21
Block3:Staircase3
Block3:G.Bedroom
Block3:WIC21
Block3:Toilet
DF
LUX
Daylighting Screen

9- Gypsum mashrabiya D1 with AC

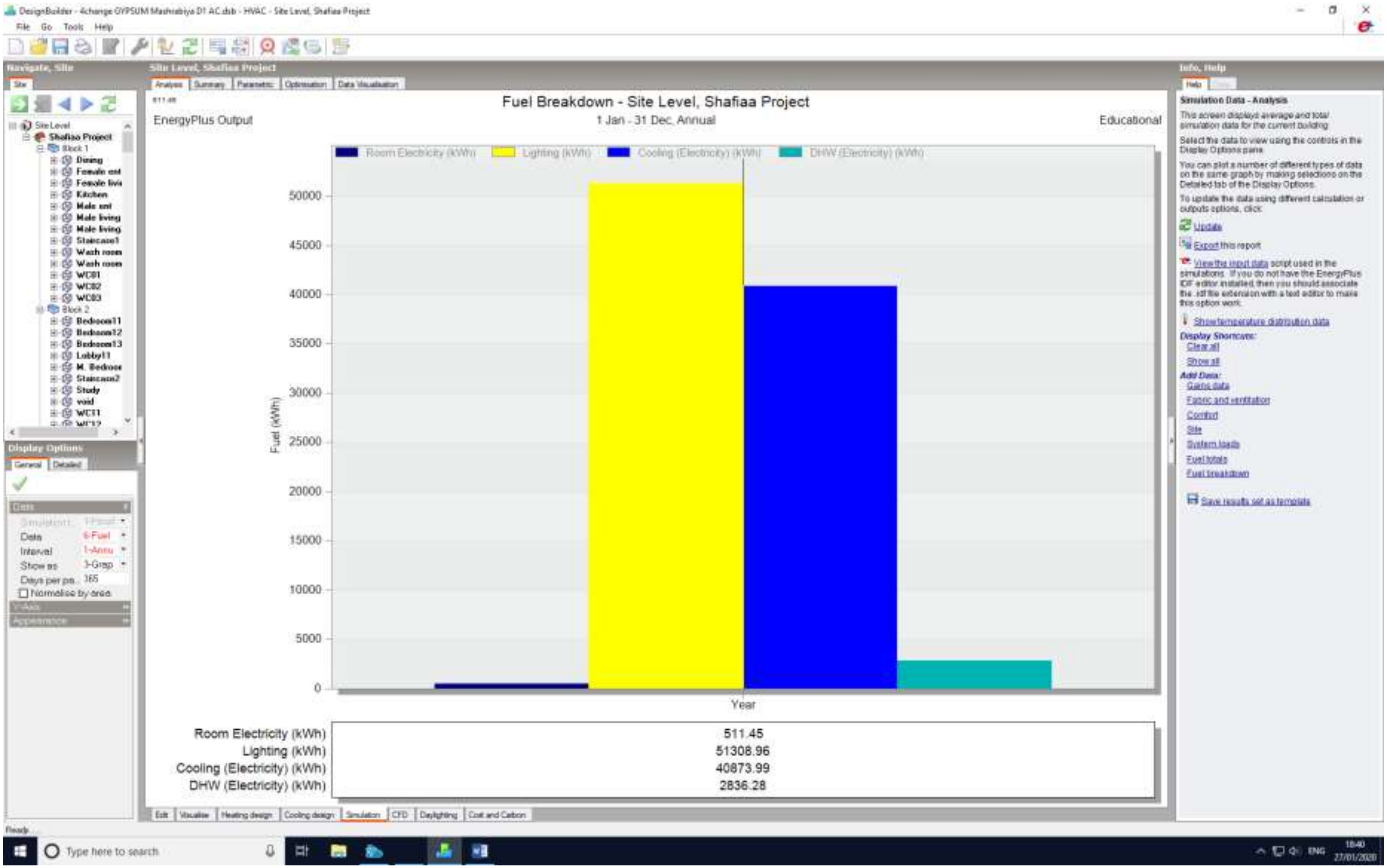



Temperatures, Heat Gains and Energy Consumption - Site Level, Shafiaa Project
Room Electricity (kWh) 511.45
Lighting (kWh) 51308.96
Cooling (Electricity) (kWh) 40873.99
DHW (Electricity) (kWh) 2836.28
Air Temperature (°C) 25.13
Radiant Temperature (°C) 26.82
Operative Temperature (°C) 25.97
Outside Dry-Bulb Temperature (°C) 28.37
External Infiltration (MWh) 4.16
External Vent. (MWh) -0.64
General Lighting (MWh) 51.31
Computer + Equip (MWh) 0.51
Occupancy (MWh) 1.56
Solar Gains Exterior Windows (MWh) 0.06
Zone Sensible Heating (MWh) 0.05
Zone Sensible Cooling (MWh) -108.08
Sensible Cooling (MWh) -110.66
Total Cooling (MWh) -163.50
Heat Recovery Sensible Heating (MWh) 0.00
Heat Recovery Total Heating (MWh) 0.00
Heat Recovery Sensible Cooling (MWh) -10.89
Heat Recovery Total Cooling (MWh) -11.39
Mech Vent + Nat Vent + Infiltration (ach) 1.46

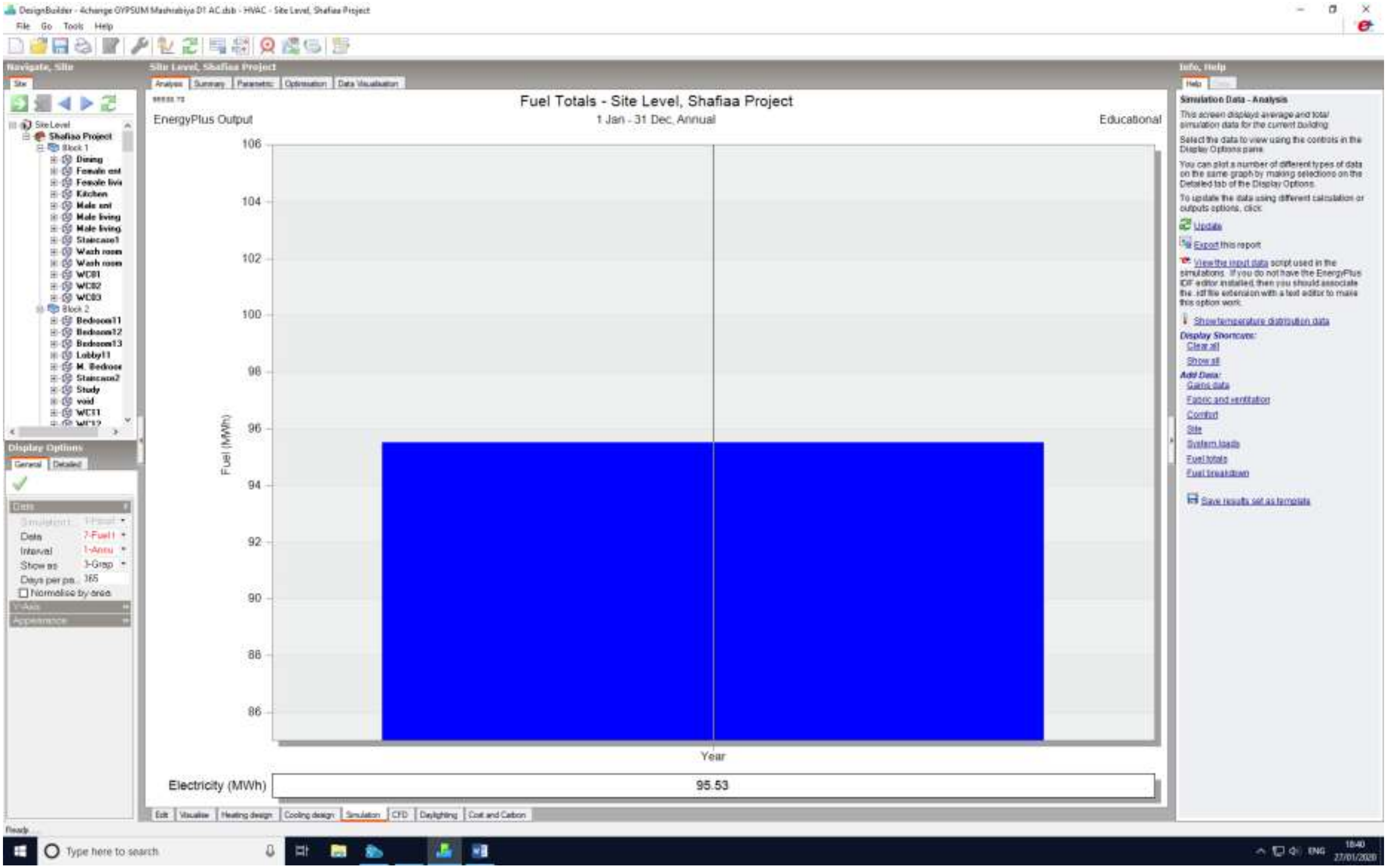


Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Year
Air Temperature (°C) 25.13
Radiant Temperature (°C) 26.82
Operative Temperature (°C) 25.97
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 58.13

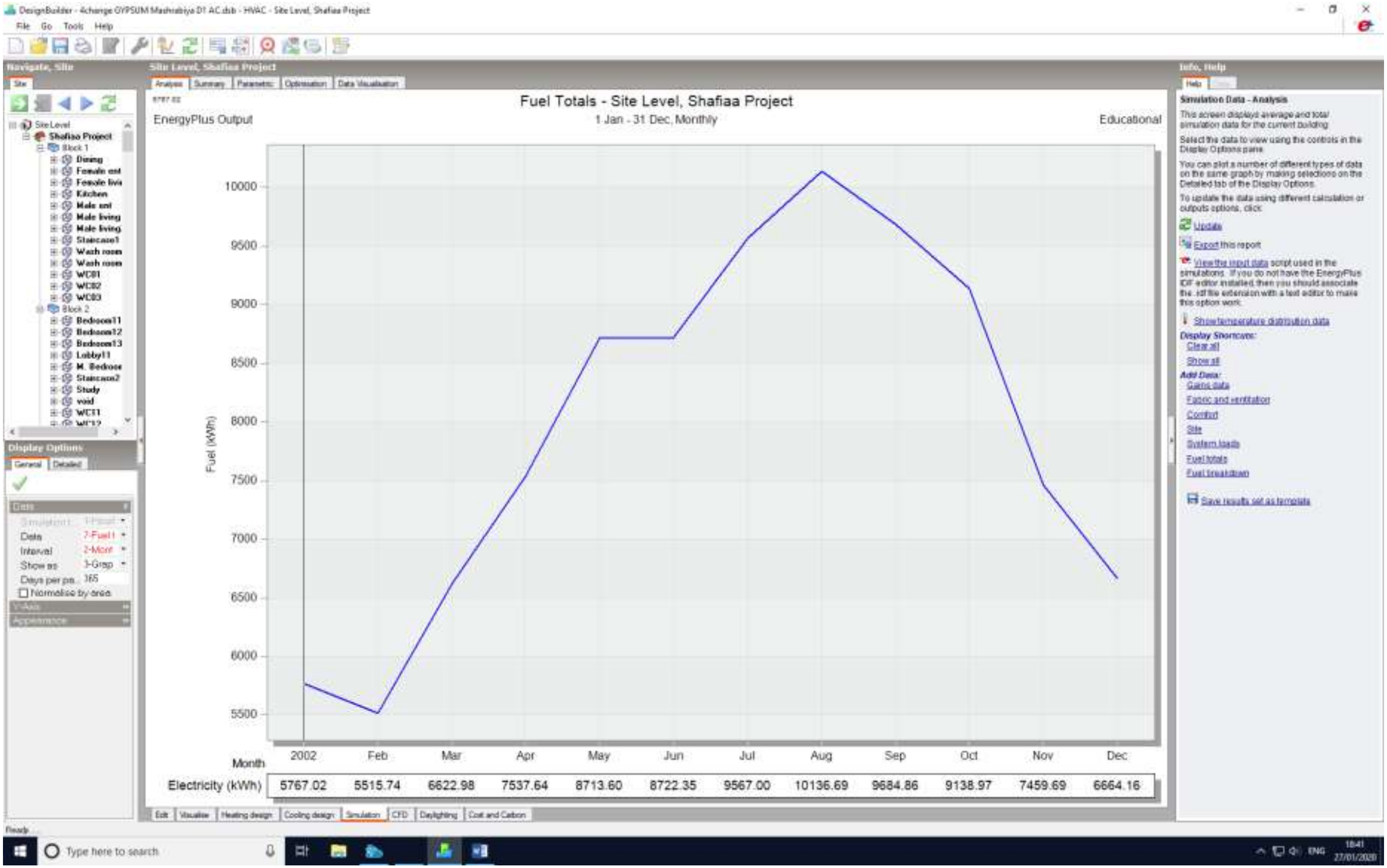

Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
Relative Humidity (%)
Percent (%)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Air Temperature (°C) 23.21 23.59 24.11 25.04 25.75 25.98 26.48 26.66 26.24 25.63 24.71 24.03
Radiant Temperature (°C) 24.11 24.67 25.43 26.76 27.74 28.05 28.72 28.86 28.32 27.55 26.25 25.26
Operative Temperature (°C) 23.66 24.13 24.77 25.90 26.75 27.02 27.60 27.76 27.28 26.59 25.48 24.65
Outside Dry-Bulb Temperature (°C) 22.79 23.57 25.04 27.63 30.57 31.01 33.16 33.13 31.41 29.87 26.87 25.05
Relative Humidity (%) 57.76 58.66 57.18 56.29 55.44 55.75 54.49 58.81 61.51 60.56 60.59 60.59


Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Room Electricity (kWh)
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
Year
Room Electricity (kWh) 511.45
Lighting (kWh) 51308.96
Cooling (Electricity) (kWh) 40873.99
DHW (Electricity) (kWh) 2836.28

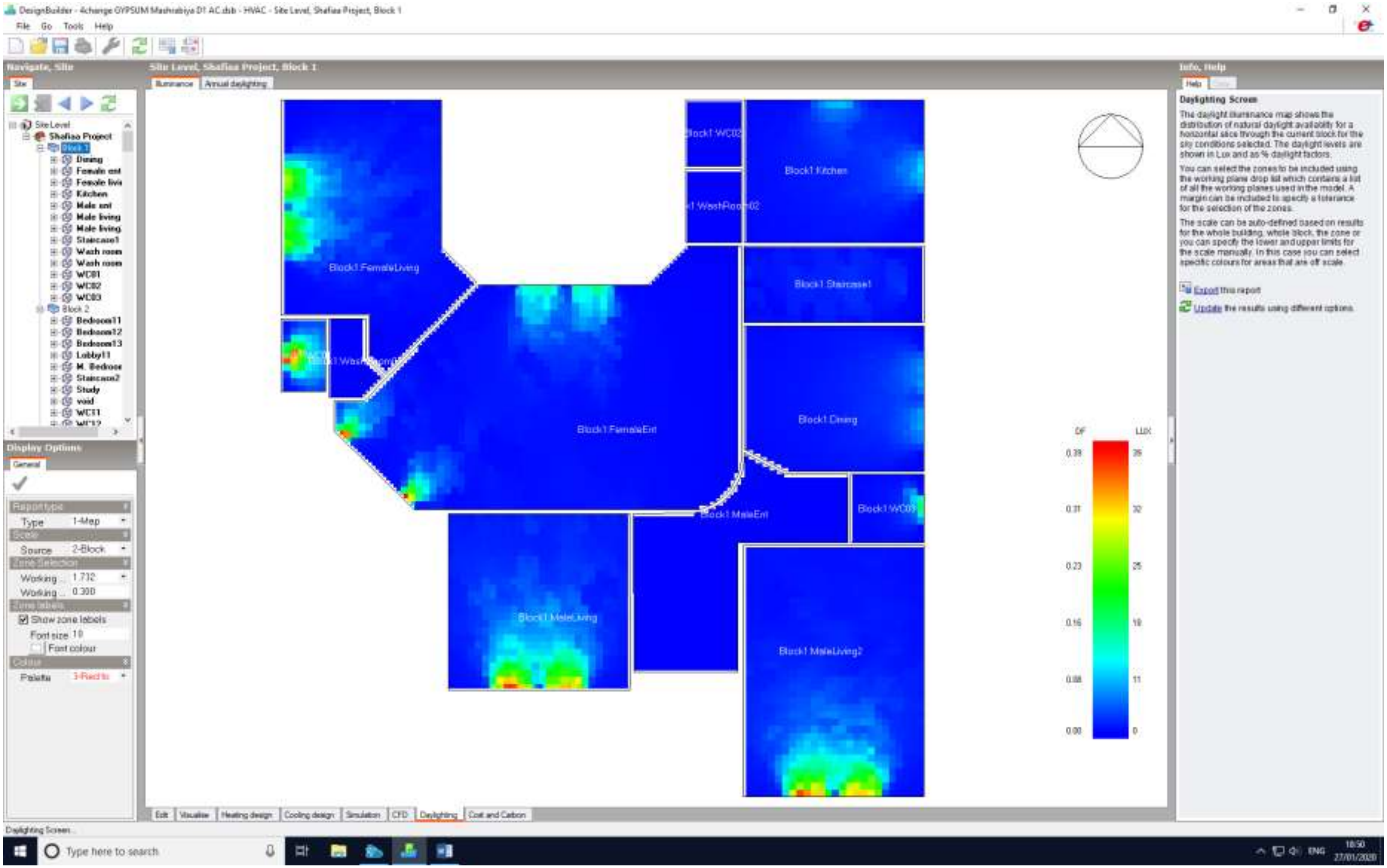
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Room Electricity (kWh)	43.55	39.16	42.20	43.88	42.20	41.19	44.90	42.20	42.54	43.55	41.19	44.90
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Cooling (Electricity) (kWh)	1124.27	1323.35	1988.48	3033.99	4079.11	4235.23	4915.98	5502.20	5189.47	4496.22	2972.56	2013.14
DHW (Electricity) (kWh)	240.89	217.58	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89

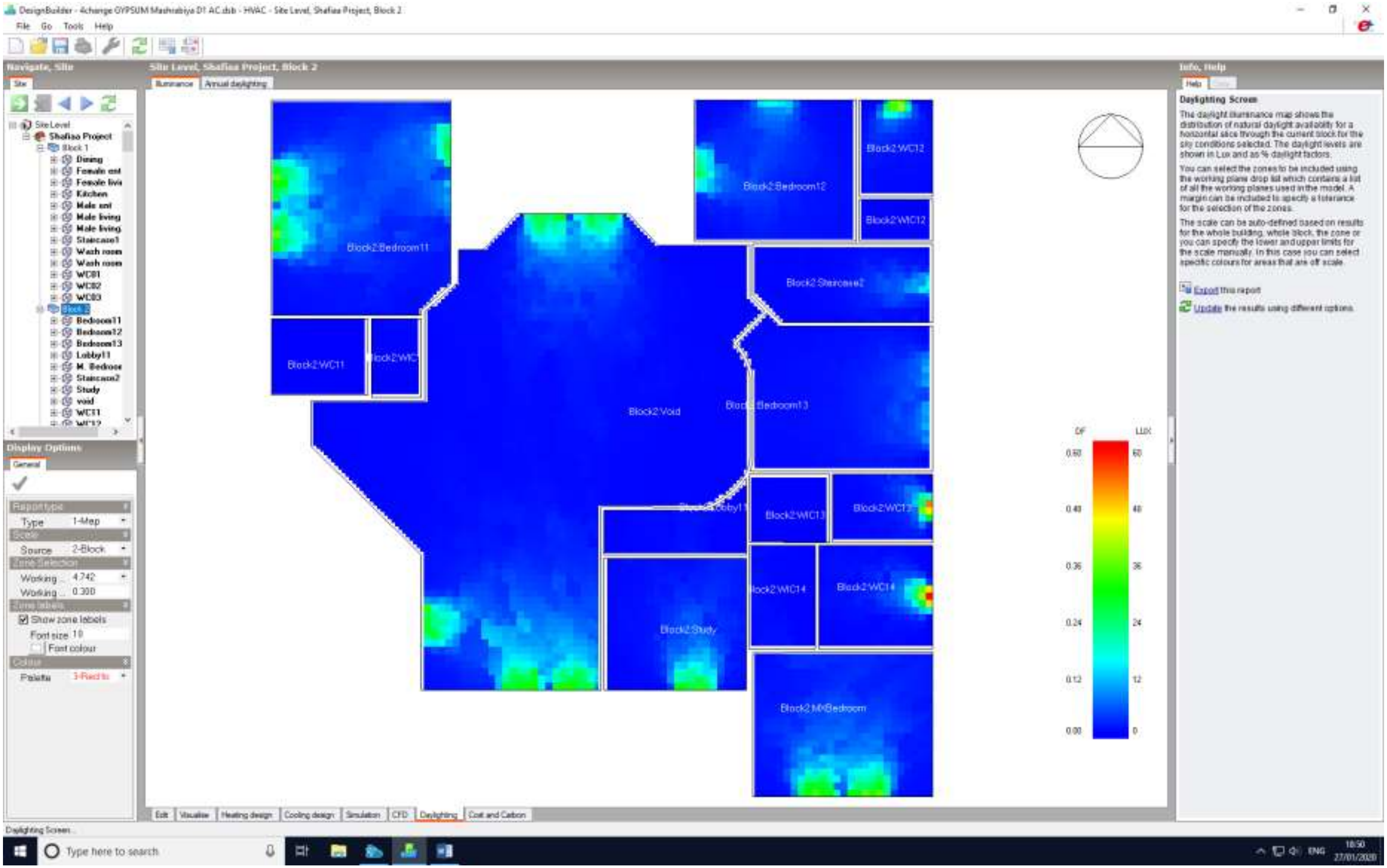


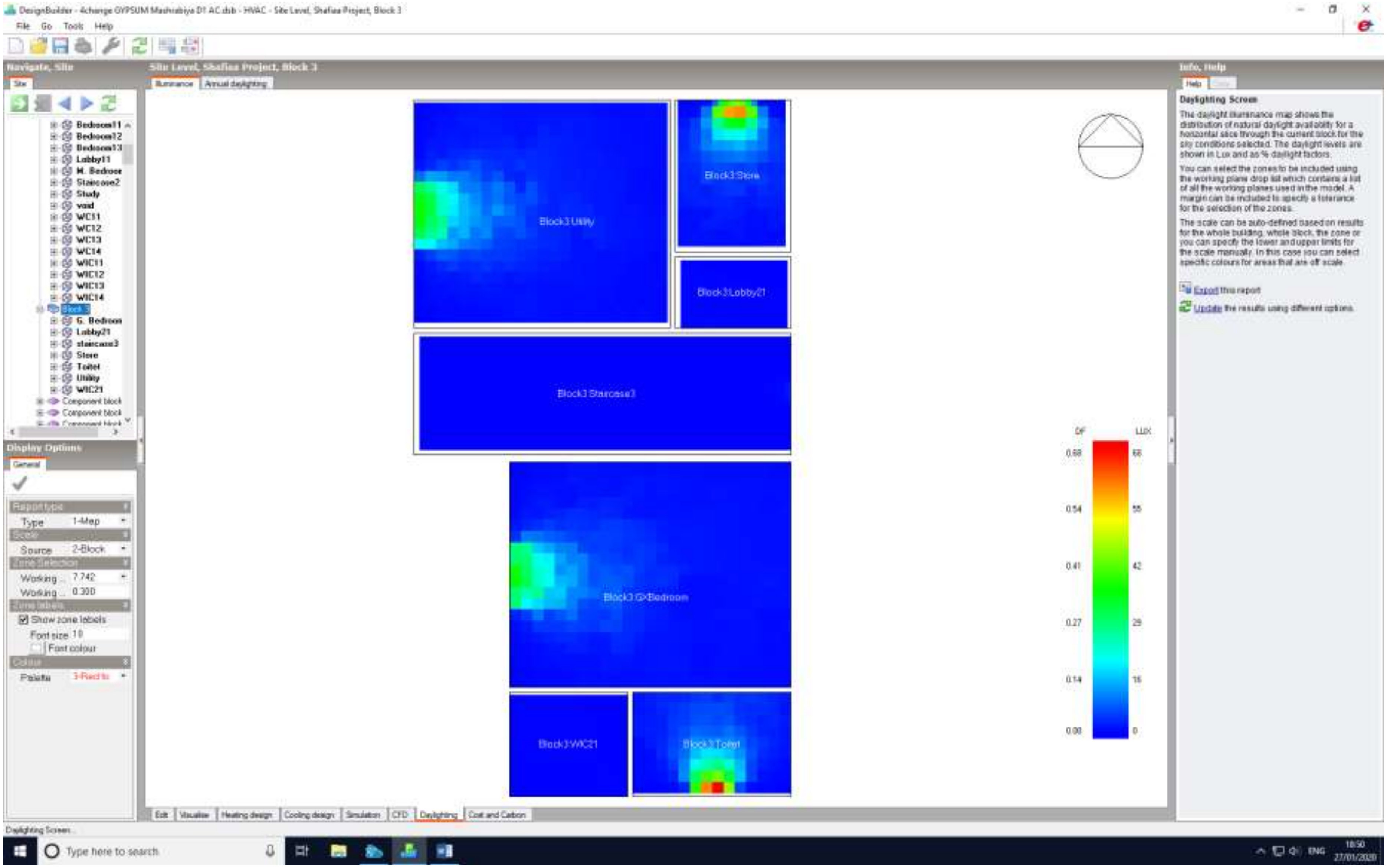
Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Fuel (MWh)
Year
Electricity (MWh)
95.53



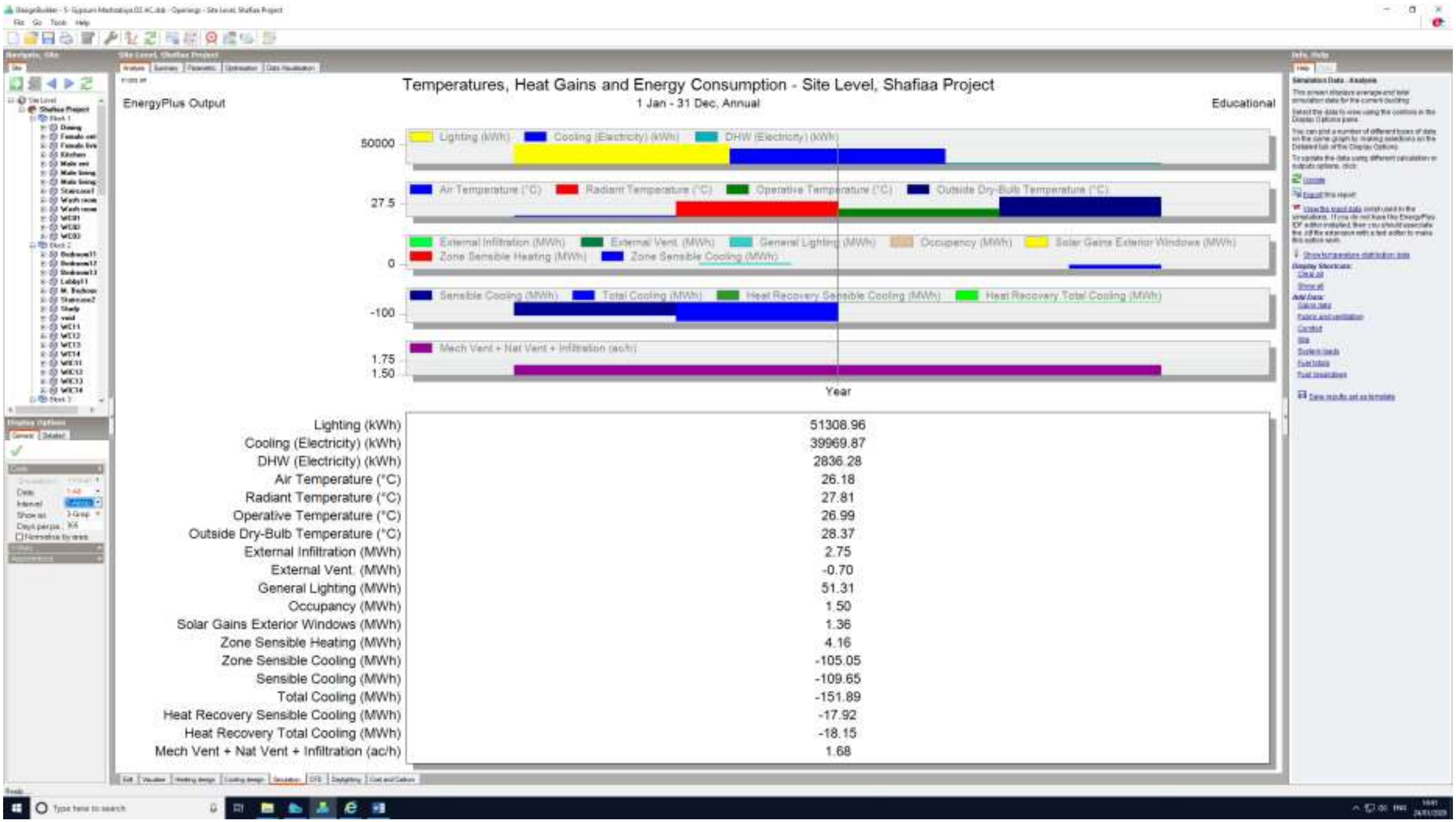
Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
Month
2002 Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Electricity (kWh) 5767.02 5515.74 6622.98 7537.64 8713.60 8722.35 9567.00 10136.69 9684.86 9138.97 7459.69 6664.16

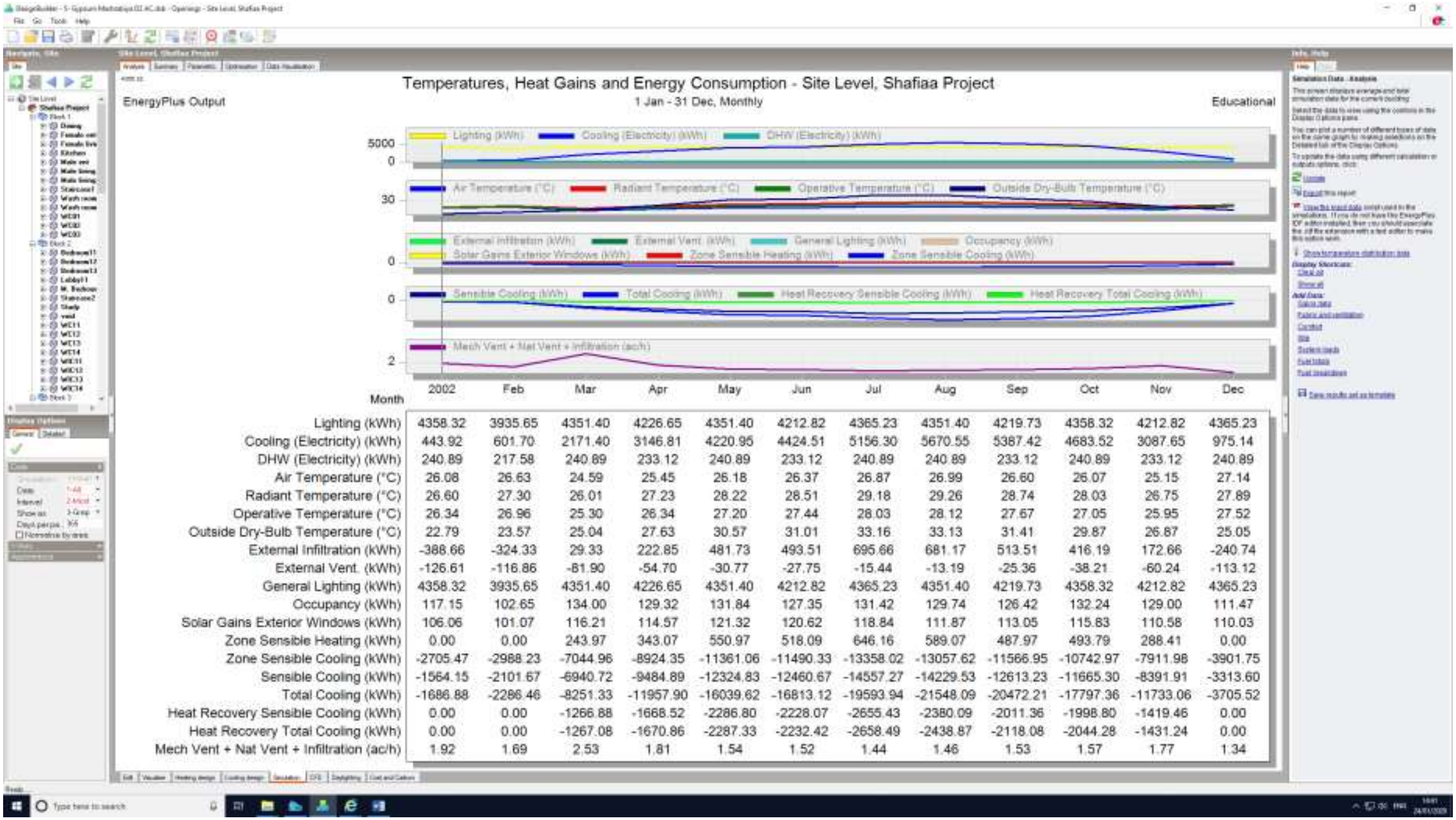

DesignBuilder - Achange GYPSUM Mashrabiya D1 AC.dsb - HVAC - Site Level, Shafiaa Project, Block 1
File Go Tools Help
Navigate, Site
Site Level, Shafiaa Project, Block 1
Illuminance
Annual daylighting
Info, Help
Help
Daylighting Screen
The daylight illuminance map shows the distribution of natural daylight availability for a horizontal slice through the current block for the sky conditions selected. The daylight levels are shown in Lux and as % daylight factors.
You can select the zones to be included using the working plane drop list which contains a list of all the working planes used in the model. A margin can be included to specify a tolerance for the selection of the zones.
The scale can be auto-defined based on results for the whole building, whole block, the zone or you can specify the lower and upper limits for the scale manually. In this case you can select specific colours for areas that are off scale.
Export this report
Update the results using different options
Site Level
Shafiaa Project
Block 1
Dining
Female ent
Female livi
Kitchen
Male ent
Male living
Male living
Staircase1
Wash room
Wash room
WC01
WC02
WC03
Block 2
Bedroom11
Bedroom12
Bedroom13
Lobby11
M. Bedroom
Staircase2
Study
void
WC11
Display Options
General
Report type
Type 1-Map
Scale
Source 2-Block
Zone Selection
Working ... 1.712
Working ... 0.300
Zone labels
Show zone labels
Font size 10
Font colour
Colour
Palette 3-Red to
Block1 FemaleLiving
Block1 WC02
Block1 Kitchen
1 WashRoom02
Block1 Staircase1
Block1 FemaleEnt
Block1 Dining
Block1 MaleEnt
Block1 WC03
Block1 MaleLiving
Block1 MaleLiving2
DF
LUX
0.39
0.31
0.23
0.16
0.08
0.00
0
11
18
25
32
Edit
Visualise
Heating design
Cooling design
Simulation
CFD
Daylighting
Cost and Carbon
Daylighting Screen...
Type here to search
ENG
18:50
27/01/2020


DesignBuilder - Achange GYPSUM Mashrabiya D1 AC.dsb - HVAC - Site Level, Shafiaa Project, Block 2
Block2:Bedroom11
Block2:Bedroom12
Block2:WC12
Block2:WIC12
Block2:Staircase2
Block2:WC11
Block2:Void
Block2:Bedroom13
Block2:WIC13
Block2:WC13
Block2:WIC14
Block2:WC14
Block2:Study
Block2:MBedroom
DF
LUX
Daylighting Screen



10- Gypsum mashrabiya D2 with AC





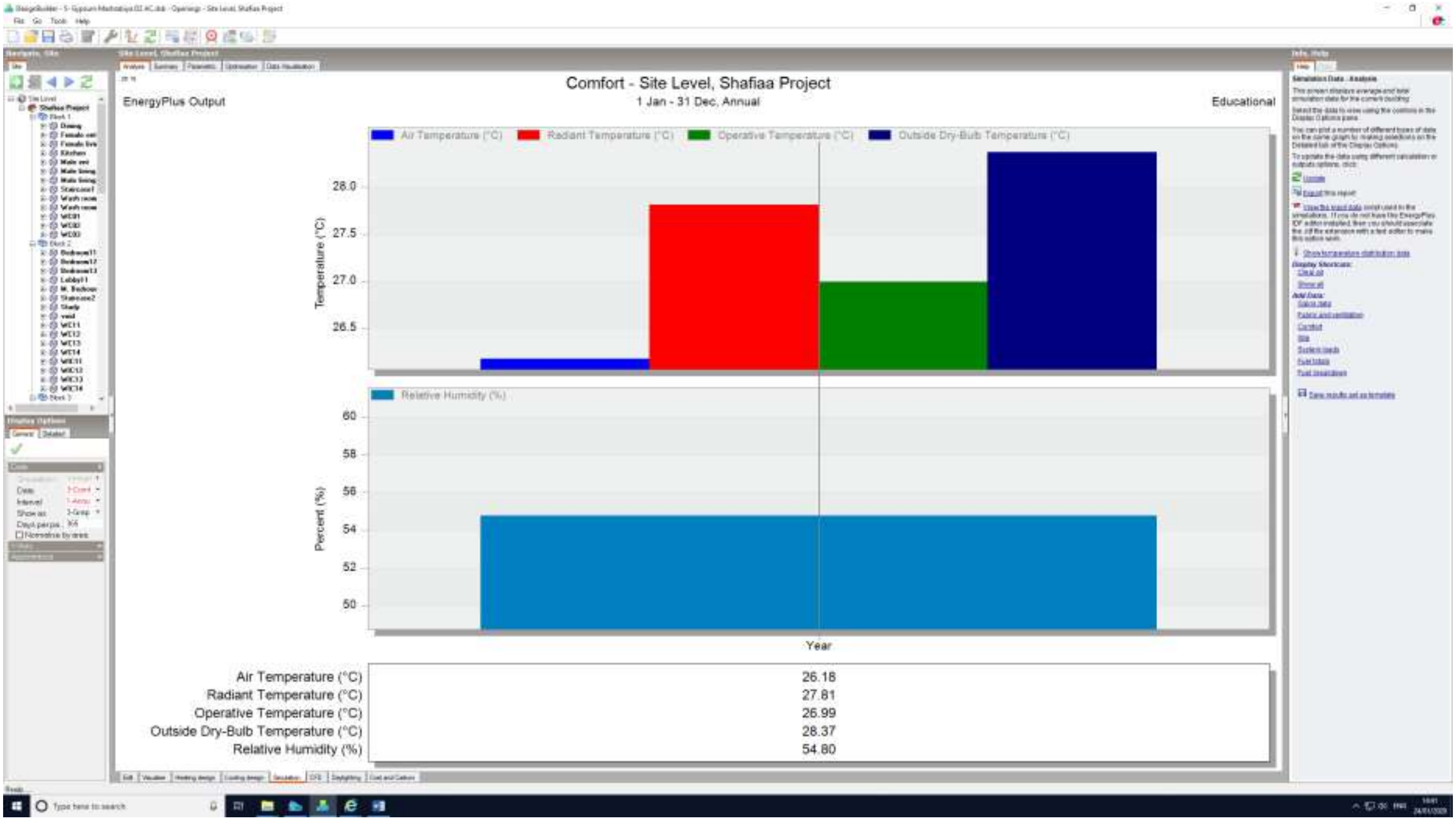
Temperatures, Heat Gains and Energy Consumption - Site Level, Shafiaa Project

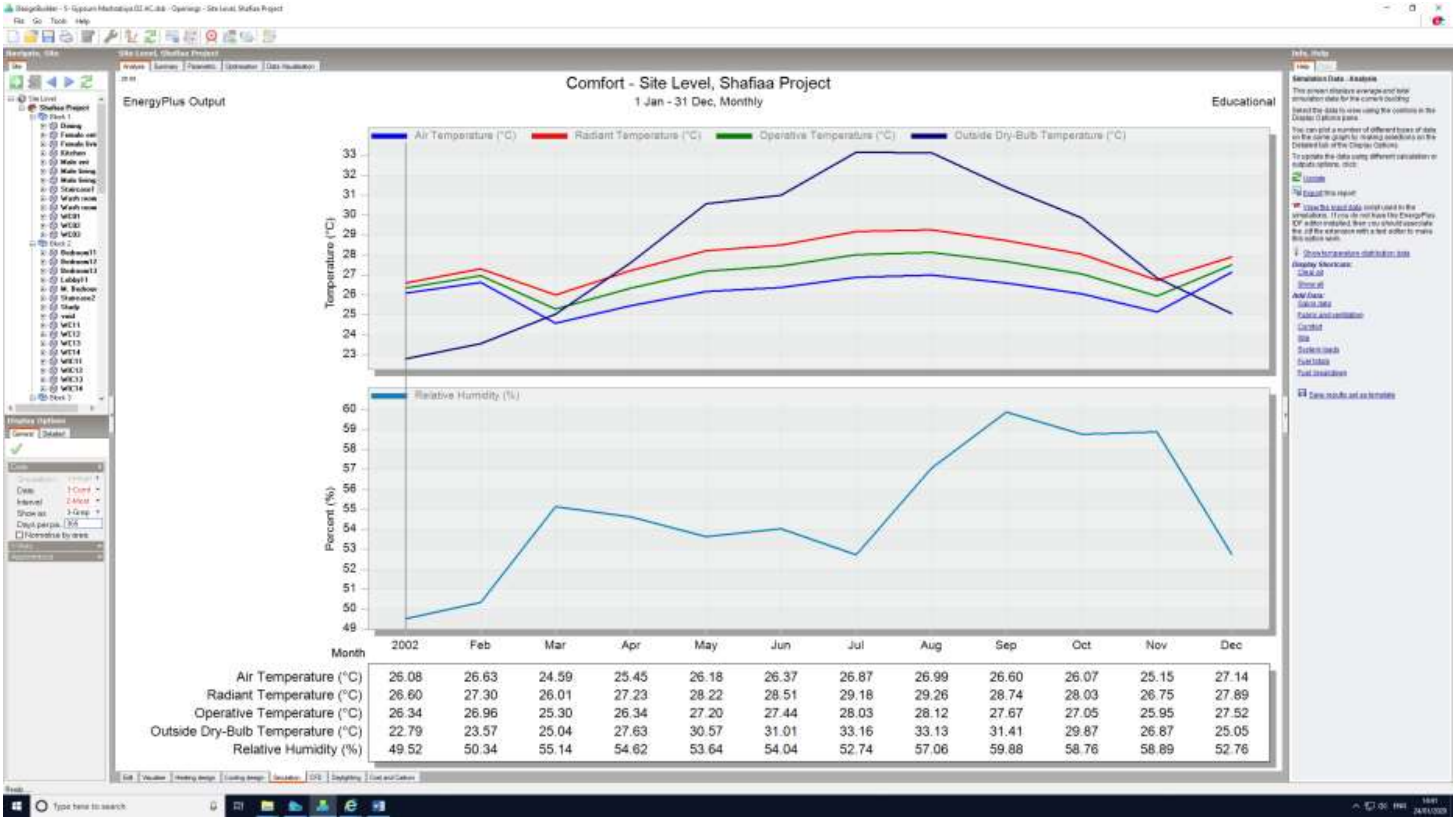
EnergyPlus Output

1 Jan - 31 Dec, Monthly

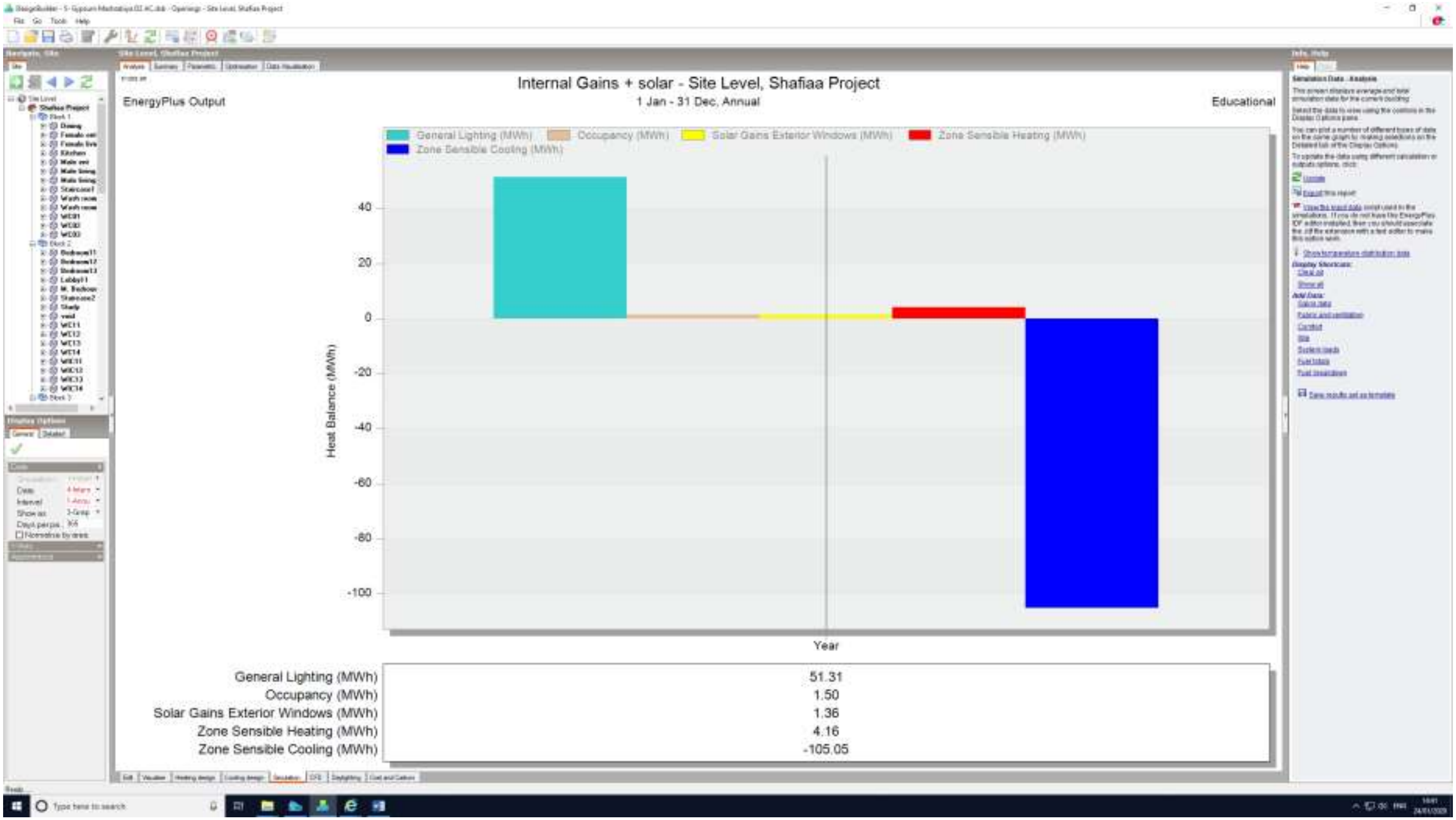
Educational

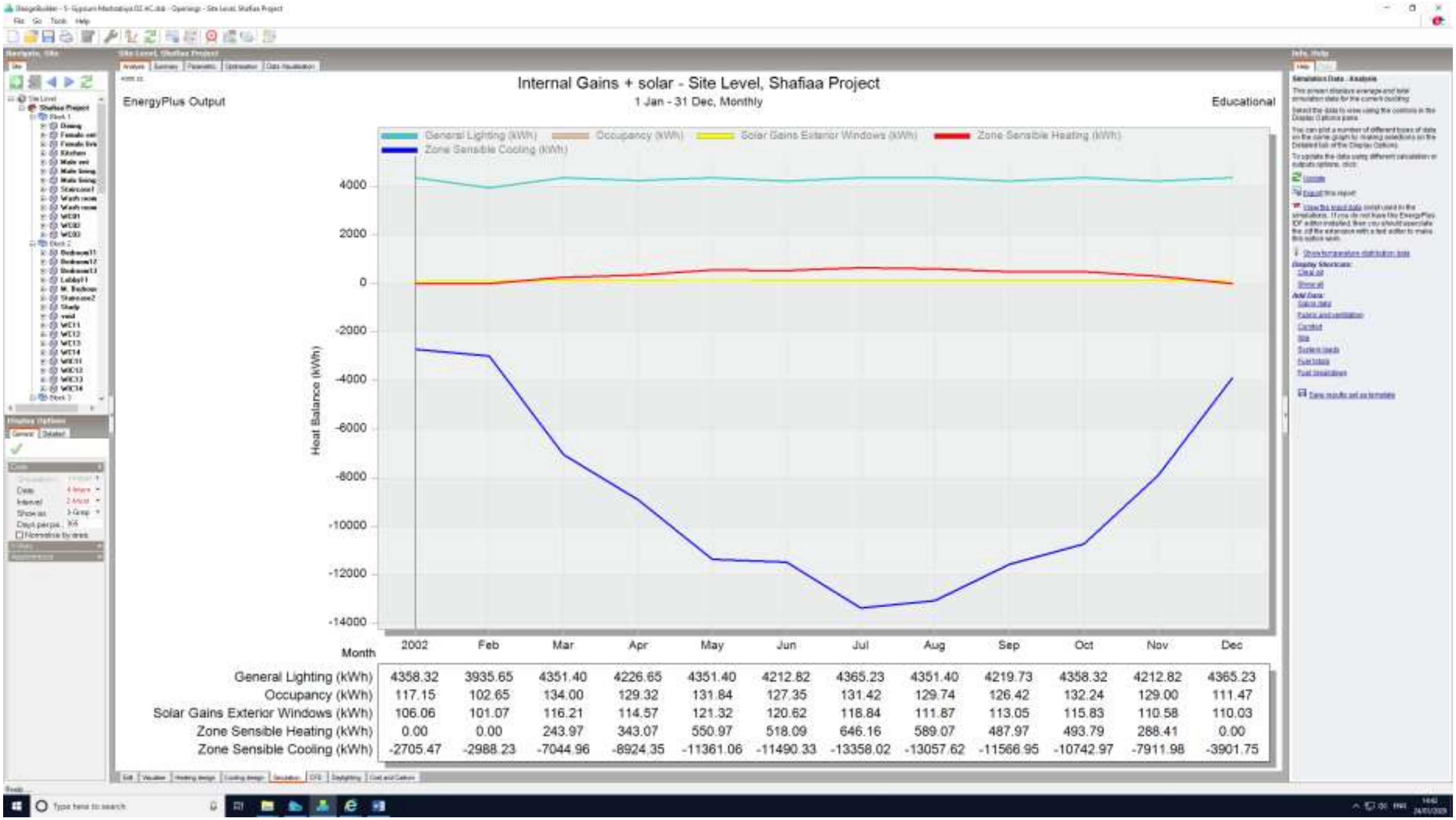
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Cooling (Electricity) (kWh)	443.92	601.70	2171.40	3146.81	4220.95	4424.51	5156.30	5670.55	5387.42	4683.52	3087.65	975.14
DHW (Electricity) (kWh)	240.89	217.58	240.89	233.12	240.89	233.12	240.89	240.89	233.12	240.89	233.12	240.89
Air Temperature (°C)	26.08	26.63	24.59	25.45	26.18	26.37	26.87	26.99	26.60	26.07	25.15	27.14
Radiant Temperature (°C)	26.60	27.30	26.01	27.23	28.22	28.51	29.18	29.26	28.74	28.03	26.75	27.89
Operative Temperature (°C)	26.34	26.96	25.30	26.34	27.20	27.44	28.03	28.12	27.67	27.05	25.95	27.52
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
External Infiltration (kWh)	-388.66	-324.33	29.33	222.85	481.73	493.51	695.66	681.17	513.51	416.19	172.66	-240.74
External Vent. (kWh)	-126.61	-116.86	-81.90	-54.70	-30.77	-27.75	-15.44	-13.19	-25.36	-38.21	-60.24	-113.12
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Occupancy (kWh)	117.15	102.65	134.00	129.32	131.84	127.35	131.42	129.74	126.42	132.24	129.00	111.47
Solar Gains Exterior Windows (kWh)	106.06	101.07	116.21	114.57	121.32	120.62	118.84	111.87	113.05	115.83	110.58	110.03
Zone Sensible Heating (kWh)	0.00	0.00	243.97	343.07	550.97	518.09	646.16	589.07	487.97	493.79	288.41	0.00
Zone Sensible Cooling (kWh)	-2705.47	-2988.23	-7044.96	-8924.35	-11361.06	-11490.33	-13358.02	-13057.62	-11566.95	-10742.97	-7911.98	-3901.75
Sensible Cooling (kWh)	-1564.15	-2101.67	-6940.72	-9484.89	-12324.83	-12460.67	-14557.27	-14229.53	-12613.23	-11665.30	-8391.91	-3313.60
Total Cooling (kWh)	-1686.88	-2286.46	-8251.33	-11957.90	-16039.62	-16813.12	-19593.94	-21548.09	-20472.21	-17797.36	-11733.06	-3705.52
Heat Recovery Sensible Cooling (kWh)	0.00	0.00	-1266.88	-1668.52	-2286.80	-2228.07	-2655.43	-2380.09	-2011.36	-1998.80	-1419.46	0.00
Heat Recovery Total Cooling (kWh)	0.00	0.00	-1267.08	-1670.86	-2287.33	-2232.42	-2658.49	-2438.87	-2118.08	-2044.28	-1431.24	0.00
Mech Vent + Nat Vent + Infiltration (ac/h)	1.92	1.69	2.53	1.81	1.54	1.52	1.44	1.46	1.53	1.57	1.77	1.34


Comfort - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Air Temperature (°C)
Radiant Temperature (°C)
Operative Temperature (°C)
Outside Dry-Bulb Temperature (°C)
Temperature (°C)
28.0
27.5
27.0
26.5
Relative Humidity (%)
Percent (%)
60
58
56
54
52
50
Year
Air Temperature (°C) 26.18
Radiant Temperature (°C) 27.81
Operative Temperature (°C) 26.99
Outside Dry-Bulb Temperature (°C) 28.37
Relative Humidity (%) 54.80



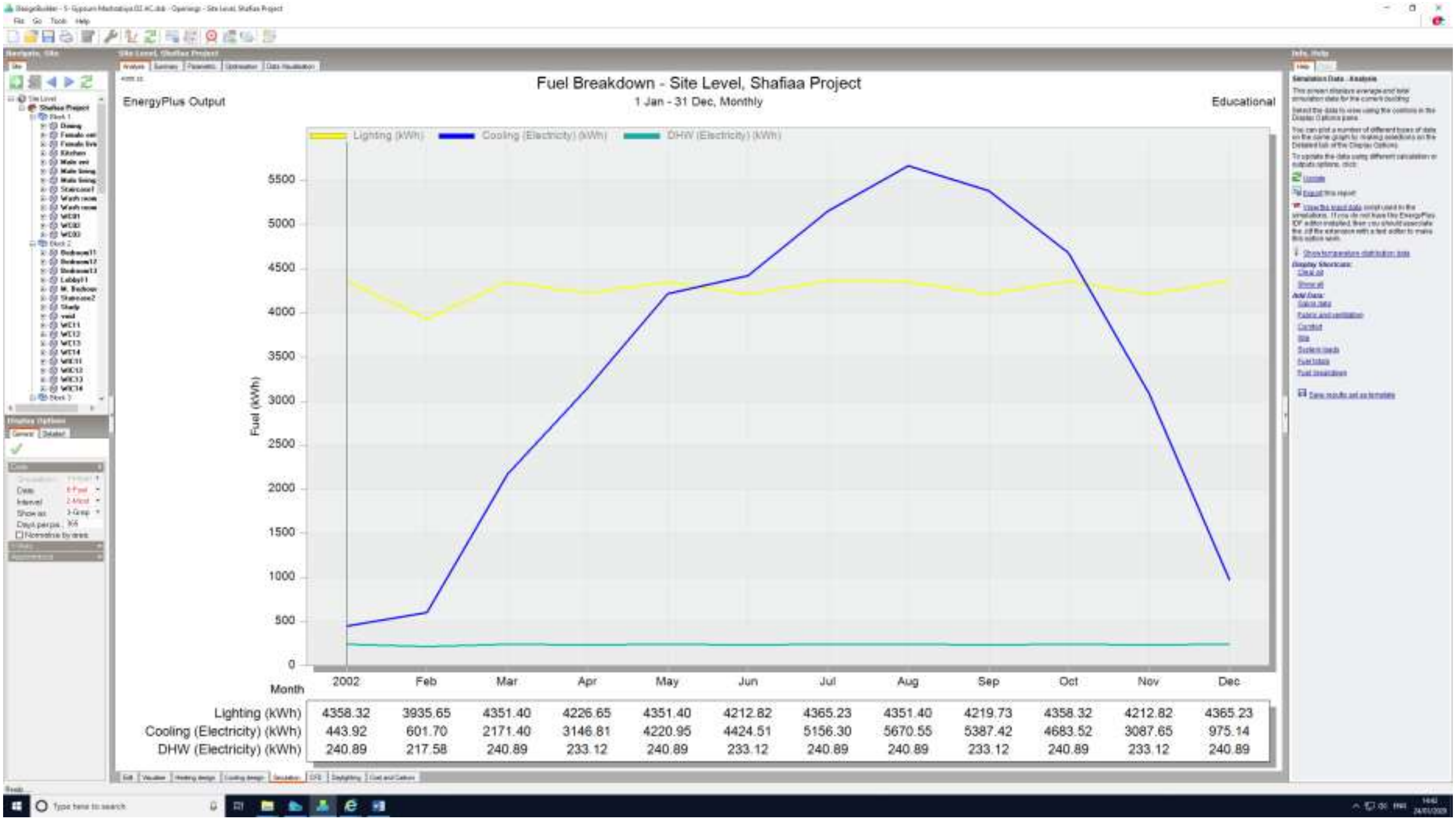
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature (°C)	26.08	26.63	24.59	25.45	26.18	26.37	26.87	26.99	26.60	26.07	25.15	27.14
Radiant Temperature (°C)	26.60	27.30	26.01	27.23	28.22	28.51	29.18	29.26	28.74	28.03	26.75	27.89
Operative Temperature (°C)	26.34	26.96	25.30	26.34	27.20	27.44	28.03	28.12	27.67	27.05	25.95	27.52
Outside Dry-Bulb Temperature (°C)	22.79	23.57	25.04	27.63	30.57	31.01	33.16	33.13	31.41	29.87	26.87	25.05
Relative Humidity (%)	49.52	50.34	55.14	54.62	53.64	54.04	52.74	57.06	59.88	58.76	58.89	52.76

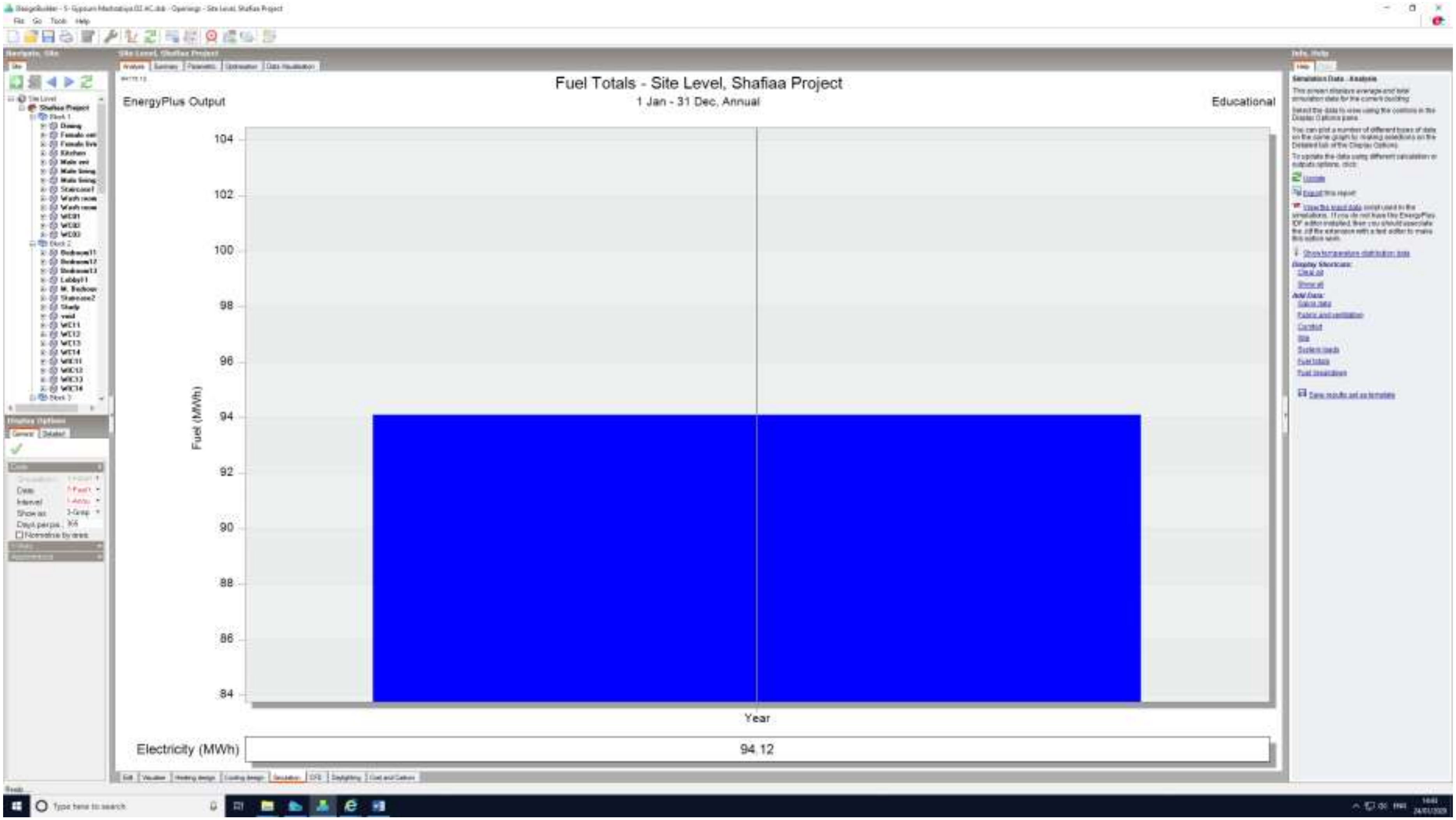

Internal Gains + solar - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
General Lighting (MWh)
Occupancy (MWh)
Solar Gains Exterior Windows (MWh)
Zone Sensible Heating (MWh)
Zone Sensible Cooling (MWh)
Heat Balance (MWh)
40
20
0
-20
-40
-60
-80
-100
Year
General Lighting (MWh) 51.31
Occupancy (MWh) 1.50
Solar Gains Exterior Windows (MWh) 1.36
Zone Sensible Heating (MWh) 4.16
Zone Sensible Cooling (MWh) -105.05



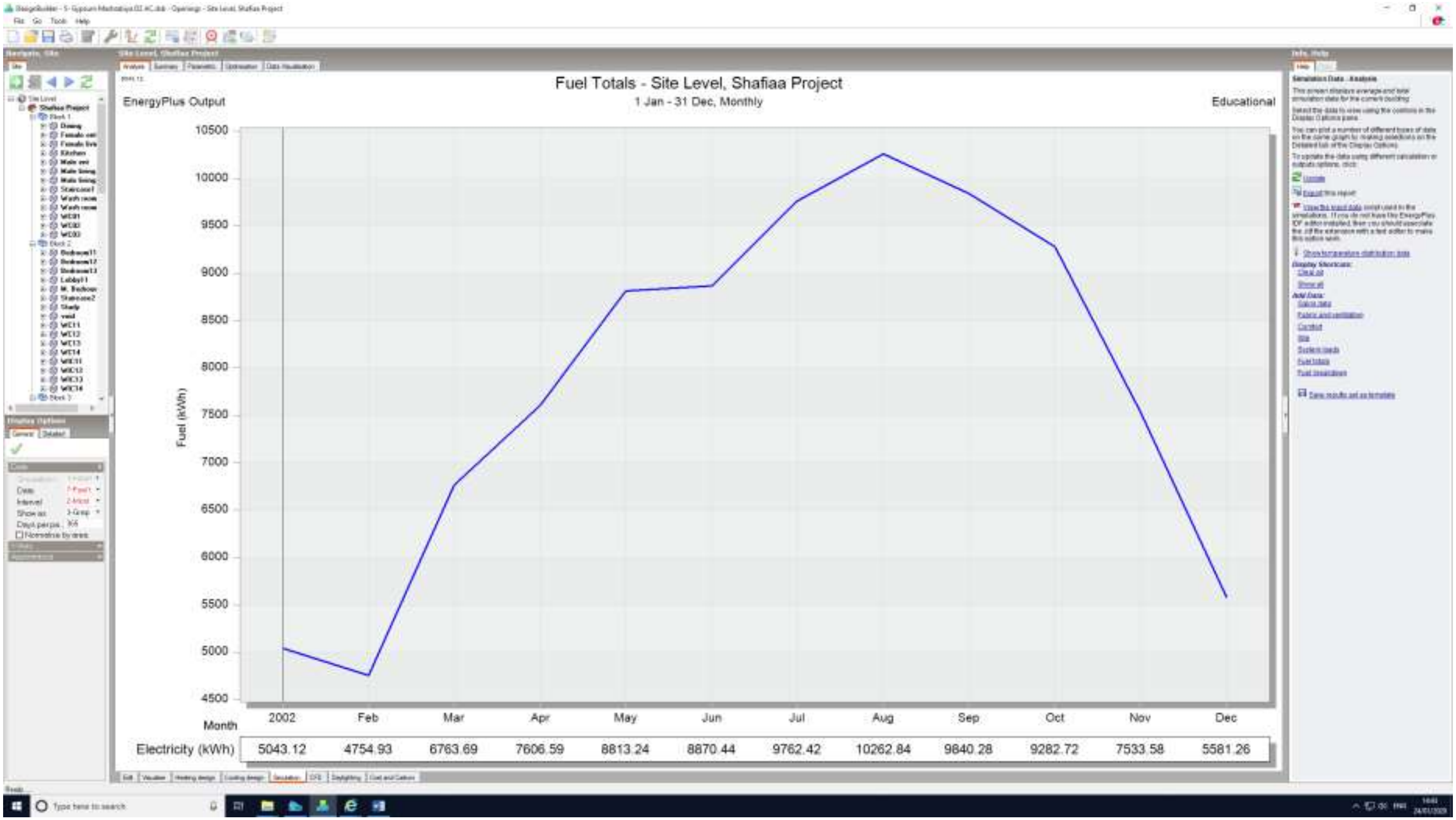
Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
General Lighting (kWh)	4358.32	3935.65	4351.40	4226.65	4351.40	4212.82	4365.23	4351.40	4219.73	4358.32	4212.82	4365.23
Occupancy (kWh)	117.15	102.65	134.00	129.32	131.84	127.35	131.42	129.74	126.42	132.24	129.00	111.47
Solar Gains Exterior Windows (kWh)	106.06	101.07	116.21	114.57	121.32	120.62	118.84	111.87	113.05	115.83	110.58	110.03
Zone Sensible Heating (kWh)	0.00	0.00	243.97	343.07	550.97	518.09	646.16	589.07	487.97	493.79	288.41	0.00
Zone Sensible Cooling (kWh)	-2705.47	-2988.23	-7044.96	-8924.35	-11361.06	-11490.33	-13358.02	-13057.62	-11566.95	-10742.97	-7911.98	-3901.75


Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
Year
Lighting (kWh) 51308.96
Cooling (Electricity) (kWh) 39969.87
DHW (Electricity) (kWh) 2836.28


Fuel Breakdown - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Lighting (kWh)
Cooling (Electricity) (kWh)
DHW (Electricity) (kWh)
Fuel (kWh)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Lighting (kWh) 4358.32 3935.65 4351.40 4226.65 4351.40 4212.82 4365.23 4351.40 4219.73 4358.32 4212.82 4365.23
Cooling (Electricity) (kWh) 443.92 601.70 2171.40 3146.81 4220.95 4424.51 5156.30 5670.55 5387.42 4683.52 3087.65 975.14
DHW (Electricity) (kWh) 240.89 217.58 240.89 233.12 240.89 233.12 240.89 240.89 233.12 240.89 233.12 240.89



Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Annual
Educational
104
102
100
98
96
94
92
90
88
86
84
Fuel (MWh)
Year
Electricity (MWh)
94.12


Fuel Totals - Site Level, Shafiaa Project
EnergyPlus Output
1 Jan - 31 Dec, Monthly
Educational
Fuel (kWh)
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
Month
2002
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Electricity (kWh)
5043.12
4754.93
6763.69
7606.59
8813.24
8870.44
9762.42
10262.84
9840.28
9282.72
7533.58
5581.26